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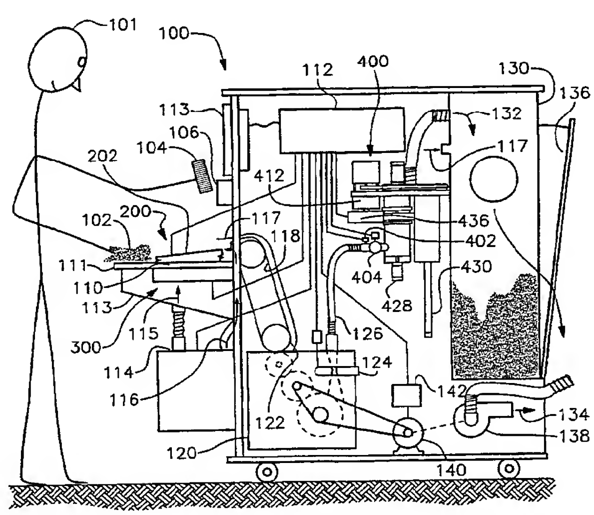
(54) Title: CONDITIONING AND TESTING COTTON FIBER



(57) Abstract: Machines for conditioning cotton fiber for testing and for processing, and instruments for testing fiber quality. High velocity conditioned gas flow through thin mats of materials are employed to condition cotton fiber. Moisture and chemicals may be introduced as aerosols as well. For color and trash measurements, an optical imaging device acquires images of both an unknown sample and a reference material in the same field of view. In an instrument classification embodiment, an instrumental classification of the sample under test is made. In a human classification embodiment, the image of the entire object field, including the sample under test and at least one reference material, is reconstructed for human classification, either locally or remotely. The image file may be transferred over the Internet to a remote location to implement "Internet Classing". Continuous compression permeability measurements are also disclosed.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Conditioning and Testing Cotton Fiber

Description

Technical Field

The invention relates generally to fiber quality measurements for cotton classing and, more particularly, to image-based instrument measurements of Color and Trash; to conditioning samples of cotton fiber prior to instrument testing and to conditioning in-process cotton for optimal processing in gins or mills; and to air flow permeability instrument measurements.

Background Art

Cotton standards are supported by the United States Department of Agriculture (USDA) through its Agricultural Marketing Service (AMS). Cotton standards, and the corresponding classing of cotton, are of great importance in determining the market value of a particular bale of cotton, as well as determining suitability of a particular bale of cotton from a gin for subsequent processing at a particular mill in view of the products and processes of that mill. AMS is responsible for preparing and maintaining such cotton standards and does so in its Standards Section located in Memphis, Tennessee.

In 1923, the United States and nine European countries entered into the Universal Cotton Standards Agreement. From that time, up until approximately 1965, USDA/AMS cotton classing "measurements" based on the Universal Standards were made entirely by humans. The human measurements included "grade," "extraneous matter" (such as bark and grass), "preparation" (which relates to smoothness of the sample) and "staple length" (long fiber content). Instrument-based cotton classing was introduced in 1965, beginning with micronaire, followed in 1980 by High Volume Instruments (HVI), which added measurements of length and strength. HVIs currently measure the fiber

qualities of Micronaire, Length, Strength, Color and Trash. Instruments for measuring Color (Rd, +b and +a, which refer to "reflectiveness," "yellowness" and "redness") and Trash (% Area) have also been developed, but Human Classer measurements of Color and Trash are still generally employed because of certain deficiencies in these methods. Some of those fiber quality measurements, notably strength and length are strongly affected by the fiber moisture content. Some proposed additional measurements, notably stickiness, nep content and cleanability, are also strongly affected by moisture content. It follows that it is very important to assure correct moisture content for fiber quality testing. Historically, this has meant allowing 72 hours equilibration time. More recently, rapid conditioning, as described below, can reduce these equilibration times to about 15 minutes. But in many cases, equilibration times of seconds are needed.

Similarly, optimal processing of cotton fiber is strongly affected by moisture content of the material. Gin and mill processing applications demand conditioning times, that is, times to approach equilibria of various processing performance parameters that are seconds, not minutes.

Accordingly, both testing and processing applications require conditioning times that are much shorter than known. Equally or more importantly, the equilibria reached throughout the sample or process materials must be uniform.

Major factors in sample preparation are the precision and accuracies of environmental conditions in which these steps take place. It is also well known that environmental conditions in the testing zones of materials property testing laboratories or instruments can strongly affect test results. This fact is generally important for fiber testing, and particularly critical for cotton, and other natural fibers, and for rayon, and other man-made fibers.

Prior to more recent developments in "rapid conditioning," for more than seventy-five years, certain fiber, yarn, or fabric tests have been conducted under so-called "Standard Laboratory Environment" or ASTM conditions of 65% relative humidity and 70°F (21°C) dry bulb temperature. Since what matters most, for good test results, is not conditions in the lab but conditions in the samples (and within the testing zones) at the time of testing, the various ASTM methods for fiber, yarn, or fabric samples further include the requirement that the samples to be tested be stored or "conditioned" in the standard environment for 72 hours prior to testing in the standard environment. This storage time presumably allows the samples to "reach equilibrium." It is noted that samples so conditioned are passively equilibrating, and that equilibrium usually refers to sample moisture content. Moisture content is the weight of water in the sample as a percentage of the dry weight of the sample. For cotton, equilibrium moisture content MC is about 7.3% at 65% RH, 70°F (21°C).

It should however be noted that moisture content is only one fiber, yarn, or fabric material property measurement whose equilibrium value is of interest. Others include tenacity, length, stickiness and neps, and such fiber properties are much more important for selling, buying and using the fibers than is moisture content. We note that moisture content affects other fiber material properties, and is therefore a very important control variable, but is not as important for marketing or processing purposes.

Whereas equilibration times of 72 hours historically yield consistent test results, such periods are unacceptably long in today's intensely competitive and information-hungry marketplace. It is therefore critically important that the tests be executed accurately and precisely, that is, with minimal bias or random errors. But testing before equilibria in the tested properties are

reached can disastrously (in profit/loss terms) reduce accuracy and precision. (Equilibrium times are different for different materials test parameters.)

Similar and sometimes more severe constraints apply to optimal process controls. Since fiber processing parameters very strongly depend upon the equilibrium fiber qualities, it is important to control said equilibrium values very rapidly, and also very uniformly.

Recognizing the severe conflict between promptly available results versus good (precise and accurate) results, the United States Department of Agriculture Agricultural Marketing Service, Cotton Division, began investigations in the early 1990's into actively and rapidly conditioning cotton samples. These investigations were remarkably successful and proved that well-conditioned laboratory air could be actively drawn through HVI samples (as opposed to passive or diffusional mass and heat transfer), which active conditioning or "rapid conditioning" enabled samples to reach moisture content or strength equilibrium in less than about 15 minutes.

Various United States Department of Agriculture papers describe "rapid conditioning." Examples are J. L. Knowlton and Roger K. Alldredge, "Experience with Rapid Conditioning of HVI Samples," Beltwide Cotton Conference, San Diego, Calif., January 1994; and Darryl W. Earnest, "Advancements in USDA Cotton Classing Facilities," Engineered Fiber Conference, Raleigh, N.C., May 1996. "Rapid conditioning" is now employed in most of the fourteen USDA/AMS cotton classing offices.

In our earlier efforts to extend USDA rapid conditioning results to small instrument classing operations having one to four HVIs (versus twenty to forty), and not having well-conditioned laboratories, it was discovered that simply drawing 65%, 70°F (21°C) air through the samples for 15 minutes yielded unacceptable test results for very dry and wet samples, and that unacceptably long conditioning times were required to

achieve good results. It was also found that sample type (i.e., variety) and size and bulk density affected test results and conditioning times.

More recently, and addressing the concerns noted just above, Shofner et al U.S. Pat. No. 6,029,316 discloses methods and a machine for "rapidly" conditioning samples of cotton fiber prior to testing. Twenty-four cotton classing samples, each weighing about 0.25 to 0.75 pounds (113 to 340 grams) are placed within a sample tray having a perforated bottom. The machine includes a sensor for measuring sample moisture content, and a controller for determining a sample specific conditioning cycle based on measured moisture content. The determined conditioning cycle is one which causes the samples to be conditioned to an optimum state for testing. Gas flow conditioning apparatus effects the conditioning cycle by driving a conditioned gas flow through the samples. Key features of such forced ventilation flows through the material are flow velocities of about 100 feet/min and sample specific conditioning cycles having variable temperatures F and relative humidities RH.

In the context of that invention, "rapidly" means conditioning a sample within about 15 minutes but much more uniformly and, also more generally, as very dry, wet or large samples can be conditioned employing embodiments of the invention.

Prior to 1993, Classer's Grade was a combination of color and leaf trash. In USDA/AMS classing, the human Classer now separately calls a color grade and a leaf grade. These Classer's calls for color and leaf grade are still the official measurements, along with a Classer's call about "Extraneous Matter" and "Preparation." Although currently unofficial, instrumental measurements of Color and Trash, as well as exploratory measurements of Short Fiber Content are made, however deficient, both to satisfy mill requests for the information and to lay the foundation and to create demand for improvements.

The Classer measurements of color, trash, preparation and extraneous matter are primarily visual, and measurements of staple length are both tactile and visual. It is appropriate to call all human classifications "measurements" in a broad sense. This is because Classers are rigorously trained to compare their observations to cotton standards immediately available to them. That is, they measure first, by comparison, then put the sample into a "class." If a Classer has any doubt about a classing call, the Classer can, sample in hand, go to a set of standards boxes to refresh the Classer's memory to improve the "call" by comparison to the standards for Grade and Staple.

Considering in particular the current methods of human visual fiber quality measurements, the Classer holds a sample from a bale and visually examines its appearance in good, meaning standardized, illumination. Making the measurements of Color Grade and Leaf Grade physiologically and psychologically amounts to comparing the images falling on the retinas and perceived by the brain with images from memory or, for confirmation, images from physical standards. The procedures of making such measurements are learned in extensive training. "Classer's Call" means that the Classer has measured the object and judged it to fall within or near to a standard or, if not, he or she comments why.

Since approximately 1950, various forms of the "Micronaire" air flow permeability measurement have been widely used in the classification of cotton. The permeability measurement was originally calibrated in terms of linear density or fineness, with dimensions in the United States of micrograms per inch, with a typical and good value being 4 $\mu g/in$ (10 $\mu g/cm$), and with ranges in value from as low as 2 $\mu g/in$ (5 $\mu g/cm$) to as high as 7 $\mu g/in$ (18 $\mu g/cm$). Most varieties, when "normally matured," have values in the range of 3 $\mu g/in$ (7.6 $\mu g/cm$) to 5 $\mu g/in$ (12.7 $\mu g/cm$). It was later found that this fineness

interpretation was incorrect, since the calibration between permeability and true weight fineness could not be robustly adjusted to fit most cotton types, so the fineness dimensions were dropped. But since the measurement was found to be useful for processing, particularly for "wastiness" and for other processing problems, the measurement was standardized and its use grew. Micronaire became the first non-human based measurement to enter the trading of cotton, widely, and was introduced officially into AMS classing in 1965.

In the standardization of this simple measurement, a known (by a precision balance) sample mass is compressed into a known, fixed volume, air is forced through this compressed plug, and the resulting air flow permeability, a ratio of flow rate to pressure differential (usually to the one half power), is calibrated in terms of "accepted" values of micronaire provided by the USDA. Thus the measurement is calibrated on cotton at a fixed bulk density of the plug or, alternatively stated, at a fixed compression volume for the fixed and known mass. Nearly 50 years of experience with this measurement substantiate its usefulness but, equally strongly, its shortcomings. Other apparatus has been offered which provides permeabilities at two compressions of the same sample mass. From these data, additional fiber properties, including Maturity and Fineness, can be inferred, based on calibrations for these fiber qualities. These "double compression" testers were manufactured by Shirley Developments, Manchester, England and Spinlab, Knoxville, TN, and called the Fineness and Maturity Tester and the Arealometer, respectively. These instruments are not widely used because the calibrations are not sufficiently robust and the results are very operator and sample state sensitive. The Arealometer is no longer manufactured.

Further adding to the difficulties for these measurements, definitions for Maturity and Fineness are not widely agreed. The better or "more unbiased" of the many

definitions in use relate to the fiber cross sectional shape and to the fiber cross sectional area, respectively. Such data can only be produced by image analysis of carefully prepared fiber cross sections that are too slow for commercial use, even with modern image analysis methods.

Disclosure of the Invention

Embodiments of the invention condition samples of cotton for satisfactory testing (or processing) in a matter of seconds, and do not require conditioned laboratory or processing facility space, as the conditioning is accomplished internally to the testing instrument or processing machine. Key features of the invention are high velocity gas flows through thin mats of material and delivery of moisture and other chemicals in both gaseous and aerosol forms. Important operational features are total moisture concentration (grams of gaseous and aerosolized water per cubic meter of gas, typically air), precisely controlled aerosol particle size distribution, the balance between aerosolized and gaseous water, and the composition and quantities of other chemicals delivered with the water.

In embodiments of the invention, an optical imaging device having a defined object field of view acquires an image for classifying an unknown sample of cotton. The unknown sample of cotton is placed in the object field of view, as well as at least one reference material. As a result, the optical imaging device acquires images of both the unknown sample of cotton and the reference material in the same field of view, at the same time and under the same measurement conditions.

In an instrument classification embodiment, an instrumental "call" or classification of the sample under test is made without reconstructing an image of the object field for human viewing.

In a human classification embodiment, the image of the entire object field, including the sample under test and at least one reference material, is reconstructed for human classification, either locally or remotely. When the image file is transferred over the internet to a remote location, we refer to the embodiments as "Internet Classing."

Inclusion of at least one reference material, having known and traceable optical properties in the object field is an important feature in both embodiments, and overcome the deficiencies of prior art methods. It is particularly advantageous to use reference materials which are similar to the samples under test. Thus cottons, whose color or trash properties are established by AMS or others, are included as reference materials. In the instrument classification, algorithms match the unknown to the knowns.

Embodiments of the invention can employ, as the optical imaging device, a high quality color scanner intended for office or graphics arts use in scanning documents. In the context of the invention, the inclusion of at least one reference material in the object field is not intended to refer to the usual and conventional calibration "strip" included in such color scanners. Such a calibration "strip" is internal to the scanner, and is generally employed to calibrate the intensity of the illumination within the scanner. The internal scanner calibration "strip" is not part of the acquired image data.

The better basic definitions referred to above in the context of Micronaire require far more rigorous permeability data; permeabilities at tens of compressions are needed, not two. Prior art apparatus is completely inapplicable for extension to acquire permeability readings from tens of compressions. For clarity, we note that the conventional term "compression" means, more rigorously, bulk density, mass of fiber per unit volume, grams/cm^3.

It is therefore seen to be desirable to provide continuous or nearly continuous measurements of rigorous

air flow permeabilities, so that robust and useful measurements of cotton Micronaire, Maturity and Fineness can be inferred. It is further seen to be desirable to enable more rigorous calibrations, in terms of basic cross sectional data.

Embodiments of the invention employ sensors to determine when a predetermined mass of fibers has been delivered to a testing chamber, allowing for automated operation without requiring an operator to guess sample weight. The testing chamber has a movable wall, and an actuator drives the movable wall so as to compress the fiber sample in a substantially continuous manner. A transducer measures the position of the movable wall, and a data processing device acquires gas flow rate through the chamber, pressure difference, and position data at a sampling rate while the wall is moving.

Brief Description of the Drawings

FIG. 1 is an overview of a machine embodying the invention, which machine measures cotton samples to produce multiple data products, including images, and additionally internally and ultra-rapidly conditions samples;

FIG. 2 is a top view of the Ultra-Rapid Conditioning module and the Color and Trash module of the machine of FIG. 1, without a pressure/distribution cover plate in place;

FIG. 3 is a side view of the Ultra-Rapid Conditioning module and the Color and Trash module;

FIG. 4 is an end view of the Ultra-Rapid Conditioning module and the Color and Trash module;

FIG. 5 is a bottom view of the Ultra-Rapid Conditioning module and the Color and Trash module, showing the optical imaging device field of view.

FIG. 6 represents the manner in which a human Classer measures fiber quality;

FIG. 7 represents image based measurements of fiber quality;

FIG. 8 is a graph depicting Trash-measurement performance of an embodiment of the invention;

FIG. 9 is a graph depicting color (Rd) measurement performance of an embodiment of the invention;

FIG. 10 is a graph depicting color (+b) measurement performance of an embodiment of the invention;

FIG. 11 is a graph depicting color (Rd us +b) measurement performance of an embodiment of the invention; and

FIG. 12 is an image of a cotton sample acquired by an embodiment of the invention.

FIG. 13 shows a pattern of reference biscuits;

FIG. 14 shows interpolated reference biscuits;

FIG. 15 shows an interpolated image;

FIG. 16 shows an alternative pressure/distribution plate to that of FIG. 3, which achieves particularly short path lengths; and

FIG. 17 shows a machine for conditioning cotton fiber in a processing environment, in particular, a cotton gin.

FIG. 18 shows the turntable in its loading/measurement position;

FIG. 19 is a side view;

FIG. 20 is an enlarged view of a portion of the FIG. 1 machine;

FIG. 21 shows the turntable in its transfer/eject position;

FIG. 22 is a cross section for FIGS. 2 and 3;

FIG. 23 is a micronaire performance graph.

Best Modes for Carrying Out the Invention

Referring first to FIG. 1, the invention is embodied in a stand-alone instrument 100 which measures fiber qualities of cotton samples to produce multiple data products, including images, and additionally internally and ultra-rapidly conditions the samples. Instrument 100 is a robust, stand-alone platform, upon which multiple fiber

quality measurement modules are placed, and is generally described in the invited paper F. M. Shofner and C. K. Shofner "Cotton Classing in the New Millennium," 25th International Cotton Conference, Bremen, Germany, 1-4 March 2000. By including internal, ultra-rapid sample conditioning, the instrument 100 enables rapid testing and eliminates the need for expensive conditioned laboratory space. The instrument 100, known as "RapidTester," thus does the work of several other instruments and an expensive laboratory air conditioning system, and does that work in the challenging ginning environment as well as in laboratories.

In a fiber testing embodiment, a thin test specimen, about 15 grams, is spread over an impervious plate having linear dimensions of about 8.5 X 8.5 inches (21.59 X 21.59 cm). The plate may be glass, through which optical measurements are made. The sample may be compressed for optical testing purposes by a perforated plate with a pressure in the range of about 0.1 to 1 pound force per square inch (6.895×10^3 to 6.895×10^4 dyne/cm^2), but a wide range of pressures are useful. When so compressed, the sample thickness is about 0.06 inch (1.5 mm). Conditioning air is driven into entry holes in the perforated plate, moves transversely through the testing sample between the perforated and solid plates, and then moves out of adjacent exit holes of the perforated plate. For testing purposes, the conditioning air may deliver only gaseous and aerosolized water, no chemicals, and the deliveries may be constant or variable, depending on the entering sample conditions and the testing objectives.

Operator 101 in FIG. 1 selects a "Classer's Sample," or sub-sample thereof, having an estimated weight of approximately 15 grams of sample 102. Such a 15-gram sample is typically 5 inches (12.7 cm) wide X 8 inches (20.32 cm) long X 0.5 inch (1.27 cm) thick, when uncompressed. The operator "swipes" permanent bale identification (PBI) tag 104 through bar code reader 106,

and prepares and introduces sample 102 into recessed conditioning/test chamber 110 of "stable table" top 111, when pressure/distribution plate 202 is retracted. (See also FIG. 2.) The operator 101 then initiates automatic conditioning/testing by causing pressure/distribution plate 202 to move over sample 102 in the recessed conditioning/testing chamber 110, compressing the sample to a thickness of less than 3 mm. Directed by a process control computer 112, the instrument 100 then automatically effects "Ultra-Rapid Conditioning" in module 200, and additionally effects testing of the sample 102 for Color and Trash in module 300. (Operator 101 can monitor and control the progress of conditioning/testing, and of all other operations, as well as examine the data products produced, stored, and communicated by system 100 via computer 112 and touch-screen display 113.)

Conditioned gas for conditioning sample 102 in conditioning/testing chamber 110 and for transporting and processing sample 102 in subsequent steps is provided by air conditioning module 114. Air conditioning module 114 provides a conditioned gas flow 116 having controlled environmental parameters such as Relative Humidity of 65%, dry bulb Temperature of 70°F (21°C), flow rates of 200 CFM (5.7 m^3/min). Conditioned gas flow 116 is conducted to the entrance 117 for both the individualizer 120 flow 122 and for the sample conditioning module 200. In a variation, gas flow 116 is split into two components, one having the fixed, standard parameters just described and a second having variable humidity, temperature, flow rate and pressure and which variable parameters are automatically controlled by a separate controller within air conditioner 114, and which parameter values are determined in accordance with optimally conditioning sample 102 within conditioning/testing chamber 110. Either flow may contain aerosolized water and chemicals, as explained hereinbelow

In overview, sample 102, having been manually or automatically placed in recessed conditioning/testing

chamber 110, with the pressure/distribution plate assembly 202 over it, is ultra-rapidly "conditioned" from above window 204 and "tested" for Color and Trash below it. Sample 102 may also be tested for moisture content in chamber 110, according to which data air conditioning module 114 is caused to optimally condition sample 102 under control of computer 112.

As a practical matter, the nominal transverse dimensions of the conditioning module 200 and Color and Trash testing module 300 are 8.5 X 8.5 inches (21.59 X 21.59 cm), the width being related to the width of standard paper in the United States. This is because the Color and Trash module 300 is based on available high quality and high resolution color scanners intended for office and graphics arts use in scanning documents. However, any transverse dimensions may be employed.

The substantially simultaneous Ultra-Rapid Conditioning by module 200 and image acquisition testing by module 300 lasts less than one minute and can be as short as approximately ten seconds, depending on scanner resolution chosen and how close in moisture content the selected sample 102 lies to an acceptable value, such as 7.3% for cotton.

At the completion of the conditioning/testing cycle, cover 202 is opened. The cover may be opened manually, or automatically upon receipt of a signal from computer 112. Sample 102, which is now conditioned for further processing and testing, is automatically or manually moved onto belt 118 for quick transport to an individualizer 120, which thoroughly opens, i.e., "individualizes," sample 102 into its various constituent entities, fibers, neps, trash, seed coat fragments, sticky points, microdust, and the like. A suitable individualizer is disclosed in Shofner et al U.S. Pat. No. 5,890,264. An alternative is for individualizer 120 to also clean sample 102 by removing trash, microdust and other foreign matter. However, in the disclosed embodiment almost all of the

individualized entities are transported in the same transport flow stream.

This processing by individualizer 120 causes the thoroughly individualized entities to be entrained in or transported by about 120 CFM (3.4 m^3/min) of conditioned air flow 122 such that the fiber and other entity concentrations transported by the gas flow at the output 126 of individualizer 120 are very low. Accordingly, the Nep content of thus-individualized sample 102 is measured with a nep sensor 124 which advantageously is built into the individualizer 120. A suitable nep sensor 124 is as disclosed in Shofner et al U.S. Pat. No. 5,929,460.

Sample 102, whose weight was guessed by operator 101 at approximately 15 grams, is at the output 126 of individualizer 120 in a highly opened, individualized state that simulates the state of fiber in important textile processing machines, especially carding. Accordingly, the state of the fiber is ideal for testing the individual fibers and other entities in the gas flow 122. One such test is the Nep test made by nep sensor 124. Other tests are Micronaire-Maturity-Fineness (MMF), effected by module 400. For Neps and for MMF, it is required that the sample weight be known, not guessed, and sample masses of nominally ten grams are commonly used for both tests.

The system aspects of the disclosed embodiment can be summarized:

1. Common flow;
2. Optimal sequence for sample tests, from surface measurements of Color and Trash to volume or weight measurements of Neps and Micronaire based on guessed weight or on precise weight;
3. Ideal sample state for simulations of actual processing (e.g., cleanability, processability, spinnability); and
4. Automatic except for selecting and introducing classer's sample, thus

eliminating operator effort and errors. System and methods can be extended to complete automation.

Image-Based Color and Trash Measurements

FIGS. 2-5 show both the Ultra-Rapid Conditioning module 200 and the Color and Trash module 300 of the machine 100 of FIG. 1. FIG. 2 is a top view, without pressure/distribution cover plate 202; and FIG. 5 is a bottom view. FIGS. 3 and 4 are side and end views, respectively.

FIGS. 6 and 7 more generally disclose embodiments of the invention for measuring Color and Trash, including Extraneous Matter. Thus the Color and Trash module 300 is an image-based system which improves the measurements of these basically important fiber qualities over current methods. Preparation can also be measured, if that data product is needed.

Comparing FIGS. 6 and 7 reveals the formal analogies between human visual classification and machine vision classification. In the image acquisition step, both require good illumination of an object field and optimal positioning with respect to the imaging optics. Both form an image field on photosensitive surfaces having spatially discrete and color-resolving detection elements. And both communicate the image information to a powerful central processor for storage in a large and easily recalled memory. In the subsequent image analysis or pattern recognition step, both compare, analyze, or process the current image information with reference to corresponding image information stored in memory. Measurements or classing calls are made, based on that comparison.

Importantly, the (1) image acquisition and (2) image analysis steps are fundamentally distinct, sequential processes in the human and in the machine vision analogs. Also, image analysis is generally distinct from image reconstruction.

More specifically, an important feature of embodiments of the invention is seen in FIG. 7. Along with the unknown sample (or samples) under test, the object field includes one or more cotton standards whose colors are accurately, precisely and traceably known. Standards produced by USDA/AMS are prepared in boxes containing, typically, six known cottons which are referred to as "biscuits." The reference biscuits are viewed under the same illumination and through the same optical elements as the unknown sample(s) under test. The cotton in the biscuits is generally in the same state and pressed against the windows with the same pressures as the unknowns. The biscuits can be in sealed chambers with inert gases to diminish oxidation and other color-changing causes and thus extend the useful stable color life of the reference biscuits.

The system and method of FIG. 7 thus facilitate matching between unknown cottons and known cottons, or other reference materials. This is because the unknowns and knowns are in the same state and tested with the same optical system at very nearly the same instant in time, thus eliminating illumination, other electro-optical noise and drifts, and positioning errors. This computer-based image analysis and matching is seen to be rigorously analogous to the Classer's physiological actions, as described above and in FIG. 6, in both the image acquisition and image analysis/comparison steps, and in the electronic and in the human "classing call" step.

In an instrument classification embodiment, a high quality color scanner (intended for office or graphics arts use in scanning documents) is employed for image acquisition. About one fourth to one half the object field of 8.5 x 11 inches (21.59 x 27.94 cm) is devoted to the reference biscuits and other known reference materials and the other half to the unknown sample(s) under test. Acquired image file sizes, depending on spatial resolution (pixel size) and electronic resolution (bit depth), range

in the order of tens of megabytes to several hundred megabytes. Files near the lower end on this size range are acquired and analyzed in less than thirty seconds, currently. Accuracy and precision can approach fundamental limits associated with the color standards used.

The same method can be extended to measurement of trash, including measurement of the color of each trash particle, as well as its shape. This enables classification of bark and grass and other types of foreign matter. Another data product or measurement is preparation via surface texture.

The reference or "target" cottons are formed from universal cotton color standards prepared by the USDA/AMS in Memphis. However, reference cottons from any country, or even from an individual gin or mill, or a mix, may be used for the reference biscuits. Other reference materials can be employed in addition to cottons. This will be important as there is movement toward absolute or Commission Internationale l'Eclairage (CIE) color measurements.

FIGS. 2-5 more particularly depict an embodiment in which color scanner-based image acquisition/analysis technology is adapted to the measurement of cotton Color and Trash. The Ultra-Rapid Conditioning process of module 200 takes place above window 204 in FIGS. 3 and 4. Sample 102 is pressed against window 204 by downward (on perforated plate 212) and upward (on window 204) suction forces explained above. The Color and Trash measurements of module 300 take place below window 204. Color scanner apparatus 302 is attached to the bottom of stable table 111. This stable table 111 is made of aluminum or heavy plastic and is mounting on soft springs (not shown) which are highly damped and which mass-spring-damper system has the purpose of isolating the scanner from vibrations. Conditioned gas flow 115 from conditioner 114 in FIG. 1, which includes filtering, is directed into cabinet 113 to maintain cleanliness of the optical components. Scanner

302 may be a Hewlett-Packard 6000 series scanner or equivalent and includes a scan head 304 which is driven along rails 306 by a stepper motor (not shown). Flexible signal cable 308 connects the several thousand pixel, linear arrays, one for each of the three colors Red, Green and Blue 320, to on-board electronics module 310 which is turn connected to computer 112.

Computer 112 controls scanner 302, acquires and stores its large quantities of data, and operates upon or analyzes these acquired data to generate scientific measurements, which is the functionality of interest in the first embodiment. In another embodiment, computer 112 is used to produce images for human classification, or for communications to other computers, including communications over the internet, where scientific measurements or human classifications can be made.

The processes of: (1) scanning an object field, and acquiring thereby an image file of raw data; and (2) operating upon those acquired raw data to produce a viewable, communicable or analyzable image field, are sequential and very sharply distinct. These processes can be characterized as (1) image acquisition and (2) image reconstruction or recording and reproduction. One analogy is acquisition of a photographic negative from which positive prints are made to reconstruct the image. Another analogy is music recording and subsequent reproduction. Appreciating the nuances of the separate processes of acquisition and analysis or recording and reproduction facilitates understanding the limitations of both processes, including spatial and electronic resolution, dynamic range, various nonlinearities, noise and most particularly, fidelity.

Scanner light source 312 in FIG. 4 illuminates the object field above it 330, FIG. 5, with typical incident rays 313. Incident rays 313 originate directly from elongated lamp 312 or after collection by mirrors 314. Reflected light from object field 330, represented by

typical reflected rays 315, hits mirror 316, is collected by lens 318, and imaged onto linear array 320. Stability of the illumination source 312, with respect to intensity in time and in space, and to spectral emissions, is one of the major causes for poor color fidelity. Embodiments of the invention minimize this cause.

For an RGB color scanner with 600 dots/inch (236 dots/cm) or pixels/inch (236 pixels/cm) "optical" resolution and 8.5 inches (21.59 cm) object field width dimension, the number of pixels in the three color channels of linear array 320 is 600 x 8.5 x 3 = 15,300 pixels. For an 11 inch (27.94 cm) length object field with 600 dpi (236 dots/cm) resolution and three colors there are 11 x 600 x 3 = 19,800 pixels. Thus there are 303 million pixels of spatial resolution in the raw image. If the electronic resolution or "bit depth" is 12 bits or 1.5 bytes per pixel, it follows that a 600 dpi (236 dots/cm) resolution scanned color image contains 454 megabytes of data.

Notwithstanding the enormous potential for spatial and electronic resolution in color scanning technology, there are some serious limitations. Scan speed is one of them but that limitation is rapidly disappearing as the technology matures and finds wide application. In the cotton classing context of the invention, fidelity, the inability to faithfully reproduce true colors, with very small variations, is a very serious limitation. When applied to Color and Trash measurement of cotton sample 102 on window 204, currently available scanners 302 (and CCD cameras also) are so severely deficient with respect to fidelity in the recording and reproduction of color images that the technology has not previously been successfully applied to absolute, scientific color measurement. It can be noted that Color and Trash classifications, which are still primarily done by humans, have much higher standards of performance than might be expected. In the field of cotton measurements, color scanner, and CCD camera technology as well, image acquisition and analysis prior to

the subject invention have been regarded as hopelessly deficient and inapplicable for cotton classing purposes because of color infidelity. This is particularly true for Colorimetric measurements. Embodiments of the invention overcome this limitation, and set the stage for eliminating human classers, who have their own limitations, in favor of all-instrument classing.

The bottom view of Color and Trash module 300 in FIG. 5 shows that scanned field of view 330 contains, in addition to the unknown sample 102 under test, which sample 102 is pressed against window 204, known reference materials 340, 342, 344, 346. These reference materials are also shown in FIG. 4. Reference material 344, like the others, is positioned above a window 348 that is identical in optical properties to window 204 upon which sample 102 is positioned. The spacings between the scanhead 304 and the reference material windows 348 and sample window 204 are also identical, as are the pressures. Cotton reference materials having traceably known colors, described in greater detail below, are so positioned in fourteen chambers 342, 344. The pressure with which they are loaded is identical with the pressure on the unknown sample 102. The reference or "target" cottons are hermetically sealed within the chambers 342, 344.

The reference cottons are provided by the USDA AMS, Memphis, Tennessee and have precisely known color values assigned to them. By world-wide, between-government treaty agreements, these represent color data originating primarily with the cotton industry and traceable to this one laboratory. Most importantly, these standard cottons are competently and painstakingly produced by well-known methods used for calibrating human cotton classers.

Also seen in object field are other color reference materials such as Munsel papers, portions of industry-accepted color charts such as Kodak Q 60, standardized paints or inks applied to the top of the reference chamber windows 348, or ceramic tiles (because

of their long-term stability), and the like. All reference materials are "seen" through windows 348 whose optical properties are also identical.

Use of the reference materials circumvents the multitude of drifts, offsets, nonlinearities, illumination variabilities, misalignments, etc that limit color scanning or CCD camera fidelity. And they can be extended beyond scientific measurement to provide for enhancements in fidelity of color image recording and reproduction in general.

In the disclosed embodiment of the invention for Color and Trash measurements, in module 300 color scanner 302 scans object field 330 which includes unknown sample 102 and reference materials 340, 342, 344, 346. The scanner 302 acquires or records a raw image file for all objects within object field 330 having 8.5 x 11 inch (21.59 x 27.94 cm) width and length. Computer 112 operates on the raw recorded data to compare the unknown sample 102 to the known reference materials 340, 342, 344, 346, pixel by pixel if necessary, calculates the best match for Color and, independently, for Trash, and records these measurement data into memory for later use. Examples are measurement and reporting of Color: Rd, +b, and +a of 78.3, 9.3 and 0.13; and Trash: 126 trash particles having 0.16% area fraction and 42% of the particles having equivalent diameters greater than 100 micrometers. These typical Color and Trash readings are according to definitions required by the USDA for the target materials located in chambers 342, 344.

Trash measurements proceed in the same manner as color measurements, wherein reference materials having known percentage areas of leaf and other foreign matter are placed in the object field and subsequently compared to the unknown samples. Care is taken in the preparation of these reference materials that the types of trash and their size distributions are representative of commercial cotton.

It is significant in instrument classification embodiment that scientific measurements can be the end result, not necessarily images with high fidelity, as in the human classification embodiment. Indeed, a limited objective for Color and Trash measurements starts with known USDA Color and Trash data for the known reference or target cottons; the limited objective ends with matching or hitting the targets of these USDA-generated values, as disclosed above.

Thus, no image of the test cotton need be displayed for the scientific tests disclosed herein. However, satisfactory results for both matching the internal targets, for Color and Trash measurements, and for producing viewable and analyzable images, for human and for automated classing, can be obtained when standard paints are applied to the top side of windows 340, 346 and for which paints the scientific colors are determinable and stable. This means that our apparatus and methods and system can be applied to more rigorous, absolute color measurements. Accordingly, our methods and apparatus, which embrace the two types of absolute, instrumental color referencing to traceable materials in chambers 340,346 and to "accepted" materials with "accepted" colorimetric targets values in chambers 342, 344, along with unknown samples 102 in identical optical environments 330, can be extended to enhance fidelity in the recording and reproduction of images for measurement purposes in general.

It will be appreciated that embodiments of the invention rely upon the availability of advanced digital technologies for high resolution, high quality, color image acquisition, storage, processing, and communication. One salient feature is very large digital files. One such color image file, acquired with maximum resolution available now, can contain as many megabytes of data as all of the currently-reported HVI data on one million bales. Of course, these large image files are analyzed and reduced

to data products representing scientific measurements which are only a few bytes in length.

FIGS. 8-11 indicate the levels of performance achieved in the instrument classification embodiment. Scientific readings produced very favorably compare with the USDA/AMS results for Color and Trash reference materials, over a wide range of color and trash values. FIG. 12 is a composite image containing an image of both samples from a bale and an overlay of the scientific measurements for the bale having the indicated permanent bale identification bar code. It may be appreciated that our scientific measurements are obtained with the new technologies and methods herein disclosed whereas the reference readings are based on very old, known technologies. Particular attention is drawn to FIG. 11 which compares the color readings of our methods, marked STI, with conventional HVIs A, B and C, all in different laboratories but in a round test using the same reference cotton samples. USDA tolerances of +/- 1 unit in Rd and +/- 0.5 unit in +b are represented by the boxes. It is clearly seen that the STI data re within the tolerance boxes more frequently than conventional HVI.

To summarize the procedural steps for producing scientific measurements of color and trash by our invention, given a calibrated apparatus including known reference materials:

1. Acquire an image file of the unknown sample under test along with known reference materials in a single object field;
2. Apply color and trash matching algorithms in an image analysis step so that the internal computer interpolates the measurements and makes the classification "call."

<u>Internet Classing</u>

Cotton Classing takes on or will take on two primary forms or transitional combinations thereof:

A. Traditional Classing. Collect samples and ship them to remote sites for human and/or instrument classing. Archivally store many physical samples remotely and the data in data base(s); and

B. Internet Classing. Execute instrumental classing locally (in gins, warehouses, or mills) and transfer the fiber quality measurements, including images, over the Internet. Archivally store few samples for calibration confirmations and all data, including images, in databases.

One transitional combination of Traditional and Internet Classing, begins with acquisition of images, along with other fiber quality data, at the gin. These data and images are then transferred over the Internet for classification and other judgements and decisions, such as buy/sell decisions, by humans. Thus a human classification is made by classers looking at a high fidelity reproduction of the image file on an image display device such as a high quality color video monitor.

To better appreciate performing cotton classing and selling/buying cotton over the Internet, operation of the instrument 100 is here briefly described: An operator removes the two cut samples from the two bale sides and places both samples on the Color and Trash scanning window. The operator starts the testing process, and the instrument then automatically completes the chosen fiber quality tests which can include, color, trash, micronaire, length, strength, neps and stickiness, for example. Each sample is internally conditioned to 65% RH and 21°C, standard laboratory conditions. The image and associated fiber quality data are then sent to a local network for viewing by the ginner, and then to the Internet to be viewed by potential buyers or the producers.

The image of FIG. 7 displays both classers' samples with their associated fiber quality measurements.

Other data may be attached to inform the potential buyer of relevant information to make a purchasing decision.

Again, an important feature of embodiments of the invention is inclusion of known reference materials, especially cottons for this embodiment, in the object field of view. The primary commercial purpose for this "Internet Classing" embodiment is to enable communication of the acquired image files over the Internet with subsequent remote classification. By "Internet Classing" 500 in FIG. 13 we mean, procedurally:

1. acquisition of raw image files of object field 502 at one location, including unknown sample under test 504 and one or more known reference materials 506 in the object field;

2. communication of these files over the Internet 508 to one or more computers at one or more remote locations which reconstruct, with high fidelity, images 510 of the original object field 502; and

3. observation of the reconstructed images by trained human observers or "Cotton Classers 512."

Most importantly, human observers 512 see a reconstructed image field containing the sample under test and the standard reference materials. This means that unavoidable distortions, nonlinearities and noise in the acquisition, communication, and reconstruction steps affect both the unknown sample under test and the known reference material.

The acquisition of raw image files of the object field is precisely the same as described for the first embodiment and is further described in FIG. 7.

In another embodiment, scientific measurements can be made by a computer processor at the remote location, operating on the digital image file, without necessarily displaying it.

A few clarifying comments now complete the disclosure. Whereas the original object field 502 and reconstructed image field 510 are seen to have eight square

reference biscuits 506 surrounding the square sample under test 504, it will be appreciated that the number and shape of reference biscuits and the size and shape of the sample under test may be chosen to suit the particular preferences of the user. For some applications, linear strips of reference material are advantageous.

Although our methods make human classification from a color monitor possible, the monitor used to reconstruct the images 510 should preferably be high fidelity and calibrated and it should preferably be situated in an appropriate viewing environment. It will be appreciated that human classification of passively reflected light from a physical sample versus actively emitted light from a monitor are fundamentally different. Without inclusion of known reference materials in the recording and reconstruction steps, human classification from a monitor would not be possible.

It will be appreciated that discerning small color and trash differences is not easy, physiologically or psychologically, and all of the "tricks" of modern pattern recognition must be employed to facilitate the human judgement call. Note again the eight reference biscuits 506 seen in FIG. 13; their primary purpose is to accommodate the distortions, nonlinearities and noise of real-world color recording and reproduction apparatus over a wide range of colors. We have found that interpolations in reconstruction can enable generation of a much larger set of equivalent reference materials with a narrower range of color differences in images having different shapes. Thus the human Classer 512 in FIG. 13 would determine that the color of the unknown sample lies between that of a few of the knowns. He or she would then cause the computer, via keyboard 514 or other control means to produce interpolated biscuits with narrower color range in a pattern 517 as seen in Figure 14. The unknown sample's image is in the center and the interpolated reference

biscuits 518 surround it, from which a more accurate and precise color call is made.

Another color pattern recognition tool is seen in FIG. 15 where the unknown image is surrounded by an interpolated image 520 whose color coordinates may be varied by the Classer until a match is realized. We have found that this "trick" is particularly useful for human cotton classing. However, we have also found that the computer can surpass the human, when the matching is automated.

We note finally that the communicated digital image files may be analyzed remotely as well as be reconstructed for human viewing. That is, since the digital communication is almost error free, and since transfer of tens to hundreds of megabyte files is increasingly feasible, the image analysis from which scientific data products are produced may take place remotely and at any later time. This capability enables different analytical procedures to be employed. For example, the general algorithms by which conventional "HVI" color and trash measurements are generated at one location may not serve the specific purposes of certain Customers at other locations, who could execute unique algorithms better matched to their requirements. This is particularly important for international commerce, since the standards used by sellers and buyers in different countries are generally different.

We further note in conclusion that embodiments of the invention provide for local viewing by humans and for viewing aids such as magnification and various pattern recognition enhancements known in the art.

Ultra Rapid Conditioning

Again, FIGS. 2-5 show both the Ultra-Rapid Conditioning module 200 and the Color and Trash module 300 of the instrument 100 of FIG. 1. FIG. 2 is a top view, without pressure/distribution cover plate 202; and FIG. 5

is a bottom view. The 8.5 X 8.5 inch (21.59 X 21.59 cm) area is a glass scanner window. FIGS. 3 and 4 are side and end views, respectively.

Conditioned gas flow 116 from module 114 in FIG. 1 is conducted towards the top of stable table 111, where typically: 120 CFM (3.4 m^3/min) of the 150 CFM (4.3 m^3/min) flow 116 is drawn into inlet 117 for transport and internal conditioning of belt 118, individualizer 120, and Micronaire-Maturity-Fineness module 400; approximately 20 CFM (0.6 m^3/min) flow 210 is drawn into the Ultra-Rapid Conditioning module 200; and the remainder is discharged to the production environment. Inlet 206 is in close proximity, but not tightly coupled, to inlet 117 to minimize egresses of conditioned gas or ingresses of unconditioned gas. Valve 208 is open for maximum conditioning flow and closed for applying pressure to sample 102 for the Color and Trash measurement. Valve 208 will be seen to be unnecessary in an alternative embodiment of pressure/distribution plate 202 described later in this section.

In a first alternative, conditioned (65% RH, 70°F (21°C)) gas flow 210 enters sample 102 via perforations in perforated plate 212. This flow 210 is constrained to move in the very narrow space, typically less than about 1 to 3 mm in thickness, between the perforated plate 212 and window 204 and exits via perforated plate sidewalls 214 into plenum 216, where it is drawn into conduit 218. If there are no leaks around seals 220 or elsewhere, the exiting flow 222 from plenum 216 is substantially equal to entering flow 210. Flows 210 and 222 will, of course, vary with the mass and other properties of sample 102.

The embodiments disclosed herein evolved from the "rapid conditioning" disclosed in Shofner et al Pat. No. 6,029,316. In that earlier disclosure, large, approximately, 100 to 300 gram, samples of cotton are "rapidly" conditioned. We have now discovered that thin, less than about 3 mm, low mass samples, within the

approximate range 10 to 20 grams, will condition to proper moisture content for satisfactory testing or processing when actively ventilated in the intimately confined way, as disclosed above, in a matter of seconds, not the 14 to 60 minutes required of prior art "rapid conditioners," hence the designation "Ultra Rapid Conditioning." Extensions of prior art apparatus and methods fail to achieve the performance or the robust practicalities of the methods and apparatus recited here. We believe this failure to be in part explained by order of magnitude higher conditioning gas velocity through the fibers, of the order of 1000 ft/min (308 m/min) for Ultra-Rapid Conditioning versus 100 ft/min (31 m/min) for "rapid" conditioning. We also attribute some of the rapidity to the order of magnitude smaller sample size, 10 to 20 grams versus 100 to 300 grams. Contrariwise, if the design flow velocity of the instant, "ultra-rapid" conditioning invention were to be applied to the much larger sample mass of the prior "rapid" conditioning apparatus, the pressures and ventilation powers are absurdly excessive and/or the conditioning flow rate is ineffectively low.

By way of example, there are two alternative embodiments involving primarily valve 208 (FIG. 3) and perforated plate 212 (FIG. 3). Downward force on sample 102 in recessed conditioning/testing chamber 110 is important for the Color and Trash measurements.

In the first alternative for applying pressure to the sample 102 under test, valve 208 in FIG. 3 is open while conditioned air from module 114 is delivered to condition sample 102. In this first alternative, the holes in relatively thick and rigid perforated plate 212 are relatively large and the flow rate delivered for conditioning is high. After typically ten seconds, valve 208 partially closes and restricts flow 210 into Ultra-Rapid Conditioning module 200, thus causing a strong negative pressure or suction to be developed within pressure distribution plate 202. This suction causes

atmospheric pressure to force plate 202 downward onto sample 102. Bellows 215 and seals 220 enable the downward movement and the suction, respectively. There is also an equal and opposite upward atmospheric pressure force on sample 102 exerted by window 204. Sample pressure is important for the Color and Trash measurement.

In the second, simpler alternative, there is no valve 208, and perforated plate 212 is preferably thinner and has fewer and/or smaller holes. These smaller holes in plate 212 inherently limit the flow 210 and thus develop the suction force across perforated plate 212, directly. Open areas of the order of 10% represent a satisfactory compromise between downward force, for Color and Trash measurements by module 300, and flow rate 210, for Ultra-Rapid Conditioning. This second alternative also enables parallel operations for Ultra-Rapid Conditioning processing by module 200 and for Color and Trash testing by module 300.

FIG. 16 shows a third alternative for pressurization and for flow delivery into and out of the sample 102a under test. A pressure/distribution plate 202a is employed for pressurization of sample 102a against window 204a and for delivery and distribution of conditioning flow into 210a and out of 222a the sample under test 102a. In FIG. 16, pressure/distribution plate 202a has a series of alternating passages 230 and 232 for respectively delivering gas flow to the cotton sample 102a and for allowing gas flow to exit from the cotton sample 102a. Thus entering gas flow 210a is driven through passages 230 into the cotton sample 102a, and gas flow exiting the cotton sample through passages 232 is combined as exiting gas flow 222a.

Pressure/distribution 202a operates in a manner similar to pressure/distribution plate 102 in performing the functions of Ultra-Rapid Conditioning Module 200. But there are significant differences. First, force F 250 is applied by mechanical means, as the differential pressures

are developed internally and not available for pressurization as in FIG. 1. Second, the path lengths 213a from entry into and exit from sample 102a are much shorter than their corresponding lengths 213 in FIG. 1. These shorter paths enable much more intimate contact and higher flow rates, thus reducing conditioning times and improving uniformity. But, third and most importantly, the shorter path lengths 213a of pressure/distribution plate 202a enable delivery of aerosolized water 252 from an aerosolizer 253 uniformly. Explained next is why heretofore unknown uniform application of aerosolized water is important.

We discovered that the conditioning equilibration times for certain varieties of cotton, especially when they are very dry, below about 4% moisture content, require, when the samples are thick and the flow velocities are low, much more than the typical 15 minutes, as stated earlier. We also discovered, using operational parameters of the apparatus 200 in FIGS. 1, 2 and 3, that typical cottons will approach equilibrium in less than one minute. But the same difficult-to-condition varieties, when very dry, took several minutes to reach equilibria when the conditioning air had the ASTM standard conditions of 70°F (21°C) and 65% RH. Using the sample specific conditioning cycle procedures of Shofner et al U.S. Pat No. 6,029,316, in the apparatus 200 of FIGS. 1, 2 and 3, wherein, for example, the samples are initially exposed to 80% RH air for 30 seconds and then 65% air for 30 additional seconds, only allowed reaching equilibria in times approaching one minute.

As the speed of testing and processing is ever increasing, and even one minute is too long, it became clear that further improvements were essential and we discovered that deliveries of liquid water, in aerosolized form, to our thin mats, under proper conditioning can be effective. Delivery of liquid water to cotton fibers exploits the important and inherent feature of rapid and

large absorbency. Whereas delivery of aerosolized water, sometimes containing chemicals to aid processing, has long been applied topically in cotton processing, it has been with mixed results. The difficulties relate to the unavoidable surface collection of aerosols by filtration effects. That is, applications of aerosolized water to a thick mat yield highly nonuniform collections that are primarily on the surface. Because cotton fibers, whose diameters are about 20 micrometers, quite effectively capture, by impaction, aerosols whose diameters are tens of micrometers, it follows that very short path lengths through the mats are essential.

Returning to FIG. 16, it may now be appreciated that the short path lengths 213a, which may be as short as 1 mm or less, enable uniform delivery of aerosolized water 252 throughout sample 102a or to corresponding process mat, as explained below. Said water may contain chemicals for processing aids as desired. Note that the inlet 210a and exit 222a flows may be reversed to improve uniformity of deliveries. Note also that the path lengths 213 in FIG. 1 are much longer, of the order of 100 mm. Whereas the apparatus of FIG. 1 is satisfactory when conditioning without aerosolized water delivery, the short paths 213a of FIG. 6 are required when aerosols are used.

The total water content, in grams/m^3, the balance of gaseous and liquid water, and aerosol 252 particle size distribution, at impaction or initial interaction with the mat, are key parameters. For the fastest deliveries and equilibrations, for testing purposes, the total water content can be equal to gaseous content without aerosols, ie, 65%, the aerosol component should be larger than the gaseous component, and the volume mean diameter and geometric standard deviation of the aerosol size distribution should be about 15 micrometers and 2.0, respectively. For processing purposes, the total water content is typically much higher, as the conditioning

objectives are different. Indeed, total water content can exceed 100% or supersaturation.

Thus uniformly delivered, conditioning and equilibria times for testing and processing take on new possibilities and meanings. Subsecond equilibrations, and delivery times approaching milliseconds, are possible employing embodiments of the invention. Additionally, the importance of uniform deliveries, as accomplished with pressure/distribution plate 202a in FIG. 16, cannot be overemphasized.

An important and representative processing embodiment 270 of the invention is seen in FIG. 17 and as applied to delivery of moisture, particularly aerosolized water, to the lint flue riser 260 of a cotton gin. Lint or cotton fibers 261, after ginning and cleaning, are pneumatically transported by air flow 263 which may be 50,000 CFM in a large gin producing one 500 bale per minute. Riser 260 is typically about 20 square feet (1.9 mm^3) in area and usually rectangular in cross section.

Consider first operation without moistening station 270, which occurs if diverter panels 263,264 are rotated counterclockwise and clockwise, respectively, thus bypassing moistening station 270. Fibers and air are separated at the battery condenser 266, with the fibers captured on the exterior and forming a thick mat 267 and the air drawn out axially by a powerful fan. The mat 267 is stripped from condenser 266 by stripper rolls 268 and delivered to lint slide 269, after which it is baled. For reference, it is known to introduce sprayed aerosols onto mat 267 while it is on condenser 266 or lint slide 269, with the mixed results mentioned above because of the nonuniformities associated with surface capture. The mat 267 on condenser 266 may be 4 inches (100 mm) thick. It is also known to apply live steam or very high relative humidity air to the mat on the lint slide, also with mixed results, and for the reasons described above, wherein we

found it difficult to rapidly equilibrate cotton samples even with very high relative humidity air.

When moistening station 270 is in operation, diverter panels 263 and 264 are in the positions shown in FIG. 17, and the fibers 261 and transport air 262 are diverted to high speed condenser 271, where a thin mat 272 is formed. Transport air 262 moves through condenser 271 and at the exit is designated 265. The pressure drop introduced by the moistening station is overcome by increased suction with the battery condenser 266 fan.

High speed condenser 271 is preferably constructed of perforated stainless steel, with perforation holes about 1 mm in diameter and with about 25% open area, and may be 36 inches (91.44 cm) in diameter, 72 inches (1.83 cm) long, and rotating at a speed of 1200 RPM. The mat 272 thus formed on high speed condenser 271 and is indeed thin, less than about 1 mm. Stripper rolls 281 ensure the removal of fiber from the condenser 271, to be conveyed on to the battery condenser 266.

It is illustrative to calculate the surface density as an alternative confirmation of thinness:

$$
\begin{aligned}
\overline{W} &= \frac{500 \text{ pounds/minute}}{1200\ \pi \times 3 \times 6 \text{ square feet/minute}} \\
&= 7.37 \text{ X } 10^{-3} \text{ pounds/square foot} \\
&= 23 \text{ mg/in}^2 \ (3.6 \text{ mg/cm}^2)
\end{aligned}
$$

This average density corresponds to about 5 monolayers of fiber. It will be appreciated that this is thinner than the test sample path 213a in FIG. 16. It will also be appreciated that the illustrative dimensions and operating parameters may be modified to accommodate specific cotton gin or cotton mill applications with departing from the invention.

Aerosolized water is generated, for example by one or more two-fluid atomizer nozzles 273, with air 274 and water 275, with or without chemicals, delivered to the one or more of such nozzles to produce aerosolized water 278 at the rate and having the size distribution described

above. The aerosols are introduced into and transported by sheath gas flow 277 and primary transport flow 276. Again, what matters are the aerosol and gaseous parameters 278 as delivered at the thin mat, also as described above, as evaporation can significantly alter these parameters. Sheath 277 and primary 276 gas flows combine as delivery flow 279 whose high velocity impacts the aerosols onto the fibers in the thin mat. An impaction flow velocity of about 5000 feet/min and volumetric flow rate of about 6000 CFM are appropriate for the ginning rate of one bale/hour used here for the example. Impaction flow 279 is driven by suction means (not shown) connected to conduit 280 which draws said impaction flow 279 through the perforations of the high speed moistening condenser cylinder 271.

The rate of aerosol delivery, which depends on the ginning rate and on the initial moisture content of the thin mat, is controlled through the driving air 274 or water supplied 275 in response sensors and computers (not shown). If fibers are not present, most of the aerosol moves through the openings in the perforated condenser, so delivery of aerosols to the fiber is in part self-controlling.

<u>Electro-optical Sample Weight Control</u>

Referring again to FIG. 1, included are a volumetric flow rate sensor 402 and an electro-optional light scattering or extinction sensor 404. Volumetric flow rate sensors 402 are well known, including sensor systems 402 that communicate bi-directionally with computer 112 (RS 232).

The output of electro-optical sensor 404 is proportional to the mass concentration of entities in the gas stream at the output of individualizer 120. Such mass concentration sensors are available from ppm, Inc, Knoxville, Tennessee. Note that the volumetric flow rate 415 measured by sensor 402 is preferably (but not necessarily) substantially identical with the flow 122 at

the input to individualizer 120, which is also the same as that drawn in at inlet 117, which inflow is a major component of conditioned flow 116 from conditioning apparatus 114. The commonality of the sample 102 conditioning and transport flow, from introduction onto belt 118 to disposal into lint box 130, is one of the major system aspects of the disclosed embodiment.

Since the volumetric flow, m^3/sec, via sensor 402, is known, and since sensor 404 measures mass concentration, g/m^3, it follows that the product is a measure of the mass delivery rate, dM_e/dt M_e grams/sec. The subscript e indicates that the mass is measured electro-optically. Computer 112 records, at high scan rates of order 100/sec, the outputs of volumetric flow rate sensor 402 and electro-optical mass concentration sensor 404, computes their product, and accumulates the mass delivery rate contributions until a mass set point M_eSP, grams, is reached. (This will be recognized as a discrete summation whose limit is the integral of the mass concentration x flow rate product with respect to time.) When this set point is reached, at least two control actions are taken by computer 112: the nep counts and size distribution accumulated during the processing of M_e grams of fiber are stored in a register for later computations, and the fiber is diverted within MMF module 400 to lint box 130. Computer 112 may also speed up the feed rate for the remaining portion of sample 102 since it is of no further use in this context, as a third action.

Deriving a precisely measured sample mass is another of the major system aspects of the disclosed embodiment.

The nep data product is thus neps per gram, which can be based on either the electro-optical value M_eSP just described or a post-determined gravimetric value M_g described in greater detail below in the context of the MMF module 400. Nep size distribution is also provided. Importantly, the sample mass introduced into the MMF module

400 is known, as M_eSP, and is far more precise than operator guesswork, having Coefficient of Variation CV typically well under 10%. For some applications, the precision of an electronic balance, gravimetric determination, known as M_g, including the automated method following the MMF measurement step disclosed below, is not necessary.

The nominally 10 gram portion of sample 102 M_{esp} is then tested in MMF module 400. The remaining portion of the 15 gram estimate has been diverted to lint box 130. After testing, the nominal 10 gram portion is released onto balance 436, where mass M_g is gravimetrically measured and reported to computer 112. Mass M_g can thus be used for all data products requiring precise mass, such as neps/gram, or to adjust MMF readings to the standard 10 gram values. It is very important to note, as another system aspect, that the operator 101 has been freed from the time-consuming and error-prone task of pre-weighing samples 102.

When the balance 436 acquires the sample mass and computer 112 accepts it, computer 112 causes the sample on balance pan 412 to be drawn into suction tube 450 by opening door 453 (FIG. 7) which finally delivers this portion of the sample to lint box 130 via pipe 453. The flow 132 into lint box 130 is the same, preferably, as flows at the inlet to the individualizer 122 and elsewhere, except for short intervals of order one second when neither measurements nor transports are taking place. The flow 134 out of the lint box 130 is not the same, since other flows enter the lint box.

Filter 136, blower 140 having suctions of tens of inches water column at 150 CFM (4.2 m^3/min), and motor 140 of about two HP are well known in the art. Note that motor 140 is driven by a variable speed inverter 142 which is controlled by computer 112. Among other control parameters, system suction is maintained constant by use of the variable speed control of motor 140.

Micronaire, Maturity and Fineness Via Continuous Compression Air Flow Permeability Measurements

FIGS. 18, 19, 20, 21 and 22 show continuous compression air flow permeability measurement apparatus 400 comprising turntable 401 which rotates above baseplate 403 and is driven by gearmotor 406 via gearbelt 408. Gearmotor 406 is controlled by computer 112 via controller 407 and moves between two primary positions, "Load/Measure" (FIG. 18) and "Transfer/Eject" (FIG. 21), established by microswitches 410, 412. While rotating between these primary positions, turntable 401 is lifted above baseplate 403 by sealing cylinder 411 by just enough clearance (about 0.04 inch (1 mm)) to allow free rotation, without damage to various seals (not shown). When turntable 401 is at one of the primary positions, cylinder 411 drives turntable 401 toward baseplate 403 and compresses the seals and holds it in position for other operations, including the continuous compression of the "plug," which involves forces up to 200 pounds (90 kilogram-force).

On turntable 401 are two diametrically opposite compression/measurement chambers 405A and 405B which enable parallel testing a first sample 102 while loading a second such sample 102. Compression chambers 405A, 405B have approximately 100 small perforations (FIGS. 18 and 21), having hole diameter of about 0.07 inch (1.8 mm), through which measurement and eject air components flow. Compression chambers 405A and 405B are cylinders, closed at one end, with perforations in the cylindrical walls and endwalls. Sample handling is described first below, followed by a description continuous compression permeability measurements.

FIG. 19 is a larger scale view of FIG. 1 showing only the MMF module 400 in side view. Described hereinabove, in the systems section, is the manner in which operator 101 guesses at 15 gram sample 102 weight, which sample 102 is then conditioned and tested for Color and Trash, delivered by belt 118 to individualizer 120, and

then arrives at the input of MMF module 400 in an ideal state for permeability testing, except for the guessed weight. Precisely measured mass is essential for rigorous permeability measurements required for Micronaire, Maturity and Fineness, MMF. Use of air flow rate sensor 402 and mass concentration sensor 404, manufactured by PPM Inc., Knoxville, TN, enables the determination of mass flow rate into module 400 and how, upon reaching a mass set point M_{esp}, the MMF module 400 internally bypasses the excess part of guessed-weight sample 102. Described next below is how this bypassing is handled internally to MMF module 400, as well as the movement between the two primary positions for compression chambers 405A and 405B.

Referring first to FIG. 19, it can be seen through cutaway section 414 that the two component flow 415, comprised of air and individualized entities from samples 102, and arriving at the input of MMF module 400 from the output of individualizer 120, enters a hole 416 in valve body 418, and is conducted via solid conduit 420 into perforated conduit 422, wherein the individualized entities are separated. Air 424 moves through the entities and through the perforations in conduit 422 into a negative plenum that connects internally to suction conduit 453 which in turn connects to lint box 130. The entities 426a from original sample 102 remain within the interior of conduit 422. Upon reaching the mass set point M_{esp}, as determined by computer 112 in step-wise summation response to volumetric flow rate sensor 402 and electro-optical mass concentration sensor 404, valve body 418 is pulled down by air cylinder 428 such that the remaining portion of the guessed weight sample 102 is bypassed to lint box 130 and loading cylinder 449 is isolated. We refer to this portion of original sample 102, which achieved the desired mass set point, within narrower tolerances than operator guesswork, as 426a through 426d, as it progresses through the MMF module 400.

As soon as the longer duration of either achieving the predetermined entity set point mass 426a in perforated conduit 422 or as soon as the permeability measurement taking place in 405A is finished (see below), turntable 401 is slightly lifted by sealing cylinder 411 and rotates clockwise from the "Loading/Measurement" position seen in FIG. 18 to the "Transfer/Eject" position seen in FIG. 21. In FIG. 18, compression chamber 405A is in the "Measurement" position while chamber 405B is in the "Loading" position. There is no corresponding hole in baseplate 403 below chamber 405B, so chamber 405B is isolated. "Loading" in this case refers to the set point sample mass 426a which resides in perforated pipe 422, FIG. 20. The "Loading/Measurement" duration may be about 20 seconds whereas the permeability measurement duration may last 10 to 15 seconds.

After the turntable 401 reaches the "Transfer/Eject" position seen in FIG. 21, and which position is determined by actuation of microswitch 412, transfer cylinder 430, FIG. 20, drives the set point mass portion 426a of sample 102 up into compression chamber 405B, FIGS. 20 and 21. The top of piston 432 stops just below the bottom of turntable 401, or flush with the top of baseplate 403. Almost simultaneously, compressed air nozzle 434, FIGS. 18 and 21, blows the prior set point mass 426b portion of prior sample 102 out of compression chamber 405A, through a hole in baseplate 403, onto balance 436. The time duration at this "Transfer/Eject" position is only one to two seconds, after which the turntable 401 rotates again to the next "Load/Measure" position, as determined by microswitch 410.

It is important to note that this rotation of two compression chambers permits parallel operations, thus reducing overall testing time.

Before disclosing the continuous compression permeability measurement aspects of the invention, we complete the sample handling by noting in FIG. 19 that the

ejected sample 426d, after being automatically weighed by balance 436, is blown into hole 450 in bypass tube 451 by a pulse of compressed air from nozzle 455. Hole 450 is produced when tightly-sealed door 452 is opened by actuator 454. Ejected sample 426d then passes via pipe 453 to lint box 130. Balance 436 acquires the precise mass of sample 426d while the permeability of the next sample is being measured and while the sample after that is being loaded, again, in parallel operations involving three successive samples 102. The finished sample 426d is blown into hole 450 during a turntable 401 rotation so that the system suction is not disturbed during loading or measuring operations.

FIG. 22 is a cross sectional elevational view whose cut lines are indicated in FIG. 19. Test sample entities 426c are seen in concentric and identical internal diameter cylinder bores 461 in chamber cap 460 and turntable 401. Sample compression piston 462 sits in a similar bore in baseplate 403. These bores are precision-aligned and have diameter of nominally 2.060 inches (5.232 cm).

The samples 426c arrive in this "Measurement" position as follows: In the "Transfer/Eject" position (FIG. 21), the transfer piston 432 in FIG. 20, at its most extended extreme, is at the same flush position with respect to baseplate 403 as the measurement piston 462 in FIG. 22 is in its most retracted extreme. Turntable 401 slightly elevates and rotates, carrying sample 426b across the tops of the two pistons, fully extended piston 432 of FIG. 20 and fully retracted piston 462 of FIG. 22, whose tops are, during the transfer, flush with the top of baseplate 403 or the bottom of turntable 401. Upon reaching the measurement position, the designation of sample changes from 426b to 426c, the latter of which is seen in FIG. 22. Note also in FIG. 22 that compression piston 462 is, at its most retracted position, in a precise

position assured by the bottom of piston 462 striking the top of mounting plate 464.

Piston 462 is perforated, also with about 100 holes as in the identical compression chamber tops 405A, 405B. Air flow Q, typically in liters/min, measured by flow sensor 470, is delivered at nearly constant pressure delta p, as measured by sensor 472, typically in inches of water column, and permeates sample 426c in compression chamber bore. As the volume of the sample 426c is reduced, or the compression force on the sample is increased, the air flow permeability of the compressed sample 426c "plug" decreases. Also during the continuous compression, as y decreases from a maximum of about 2 inches (5.08 cm) to a minimum of about 0.5 inch (1.27 cm) over a time duration of about ten seconds, the force on the plug increases, as is measured, approximately, by the force F on the piston in air cylinder 466. (More accurate force measurements, those on the plug itself, which range from about zero to over 200 pounds (90 kilogram-force) force, result from installing force transducer between piston rod 465 and compression piston 462.) Permeability (Q, delta p) and force measurements are acquired by computer 112 as frequently as desired but, for our purposes, we have found that sampling rates of ten per second are adequate.

What matters in the characterization of air flow through fibrous media is rigorous measurement of the permeability of the sample 426c plug and of sample mass and compression volumes or bulk mass densities, g/cm^3. It does not matter whether permeability is measured at constant pressure with variable Q, as described above, or at constant Q and variable delta pressure. By permeability we mean $K = \Delta P/Q^2$. Thus, in most basic terms, the physical responses of air flowing through a fibrons sample 426c are completely described by the sample 426c mass, the volume yA, the compression or bulk density of that known mass in that known volume, and the flow Q through the variably compressed plug 461 and pressure differential delta p

across it, or strictly, plug permeability $K = \Delta P/Q^2$. (Gas composition and temperature and absolute atmospheric pressure are needed only in the most exacting of research-type measurements.) Our apparatus measures all of these parameters plus force F during the continuous compression precisely, accurately and with digital sampling so frequent as to approximate continuous measurement, so the air flow permeability characteristics of the unknown sample are completely described. For emphasis and symbolic simplification, air flow permeabilities K for a wide range of bulk densities P are the basic data product of the invention.

But permeability of known mass of sample at continuous compressions, no matter how rigorous or how well measured, is of little use currently in the classification of cotton. Our basic data must be "calibrated" in terms of more familiar fiber quality parameters like "micronaire," "maturity" and "fineness." These calibrations follow known statistical methods, including nonlinear multiple regressions between the continuous compression permeability readings of our MMF apparatus and samples having the desired quality parameters, which measured quality data are provided by others, including the USDA.

While specific embodiments of the invention have been illustrated and described herein, it is realized that numerous modifications and changes will occur to those skilled in the art. It is therefore to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit and scope of the invention.

Industrial Applicability

The way in which the invention is capable of being exploited and the way in which it can be made and used will be apparent from the foregoing.

Claims

What is claimed is:

1. A system for acquiring an image for classifying an unknown sample of cotton, said system comprising:

an optical imaging device having a defined object field of view;

an element for positioning the unknown sample of cotton in the object field of view; and

at least one reference material in the object field of view;

whereby said optical imaging device acquires images of both the unknown sample of cotton and the reference material in the same field of view.

2. The system of claim 1, wherein said optical imaging device comprises a scanner intended for scanning documents.

3. The system of claim 1, wherein said reference material is selected from the group consisting of cotton standards, Munsel papers, color charts, standardized paints, and ceramic files.

4. The system of claim 1, wherein said optical imaging device outputs a digital image file.

5. A system for classifying an unknown sample of cotton, said system comprising:

an optical imaging device having a defined object field of view;

an element for positioning the unknown sample of cotton in the object field of view such that said optical imaging device acquires an image of the unknown sample;

at least one reference material in the object field of view such that said optical imaging device acquires an image of the reference material in the same field of view as the image of the unknown sample; and

a processor connected to receive a digital image file from said optical imaging device and operable to compare data corresponding to the image of the unknown sample with data corresponding to the image of the reference material to determine a cotton color measurement.

6. The system of claim 5, which further comprises a storage device for storing the digital image file for subsequent reconstruction and viewing.

7. The system of claim 5, wherein:

there are a plurality of cotton standards as reference materials in the object field of view; and wherein

said processor is operable to compare data corresponding to the image of the unknown sample with data corresponding to images of the reference materials to determine the closest match.

8. The system of claim 5, wherein:

there are a plurality of color samples as reference materials in the object field of view; and wherein

said processor is operable to determine a color calibration from images of the reference materials and to adjust data corresponding to the images of the unknown sample in view of the color calibration to determine color values.

9. The system of claim 5, wherein said optical imaging device comprises a scanner intended for scanning documents.

10. The system of claim 5, wherein said reference material is selected from the group consisting of cotton standards, Munsel papers, color charts, standardized paints, and ceramic tiles.

11. The system of claim 5, wherein said processor is co-located with said optical scanning device.

12. The system of claim 5, wherein said processor is located remotely from said optical scanning device.

13. The system of claim 5, wherein said processor is further operable to measure trash within the unknown sample.

14. The system of claim 5, wherein said processor is further operable to measure preparation of the unknown sample.

15. A method for classifying an unknown sample of cotton, said method comprising:

employing an optical imaging device to acquire, within the same object field of view, an image of the unknown sample of cotton and an image of at least one reference material; and

employing a processor to compare data corresponding to the image of the unknown sample with data corresponding to the image of the reference material to determine a cotton color measurement.

16. A system employing a computer network for classifying an unknown sample of cotton, said system comprising:

an optical imaging device having a defined object field of view;

an element for positioning the unknown sample of cotton in the object field of view such that said optical imaging device acquires an image of the unknown sample;

at least one reference material in the object field of view such that said optical imaging device acquires an image of the reference material in the same field of view as the image of the unknown sample; and

a connection via the computer network for transmitting a digital image file from said optical imaging device representing the object field of view to a remote location.

17. The system of claim 16, which further comprises an image display device at the remote location whereby a human observer can classify the cotton by comparing an image of the unknown sample with an image of the reference material.

18. The system of claim 16, which further comprises a processor at the remote location connected to receive the digital image file from said optical imaging device and operable to compare data corresponding to the image of the unknown sample with data corresponding to the image of the reference material to determine a cotton color measurement.

19. A method for classifying an unknown sample of cotton, said method comprising:

employing an optical imaging device to acquire, within the same object field of view, an image of the unknown sample of cotton and an image of at least one reference material;

constructing a digital image file representing the images; and

transmitting the digital image file via a computer network to a remote location.

20. The method of claim 19, which further comprises employing an image display device at the remote location to display images of the unknown sample and the reference material in the same field of view whereby a human observer can classify the cotton by comparing the images.

21. The method of claim 19, which further comprises employing a processor at the remote to compare data corresponding to the image of the unknown sample with date corresponding to the image of the reference material to determine a cotton color measurement.

22. A machine for conditioning cotton fiber, said machine comprising:

a conditioning chamber for receiving cotton formed into a sheet-like body, said conditioning chamber being defined on one side by an impervious plate and on another side by a plate having perforations; and

an air conditioner connected for driving a conditioned gas flow through said perforations and then laterally through the cotton.

23. The machine of claim 22, wherein said sample-conditioning chamber holds a cotton sample within the approximate range of 10 to 20 grams.

24. The machine of claim 22, wherein the conditioned gas flow is driven through the fibers at a velocity of the order of 1000 ft/min (308 m/min).

25. The machine of claim 24, wherein the conditioned gas flow is driven through the fibers at a velocity of the order of 1000 ft/min (308 m/min).

26. A machine for conditioning cotton fiber, said machine comprising:

a conditioning chamber for receiving cotton formed into a sheet-like body, said conditioning chamber being formed on one side by an impervious plate and on the other side by a pressure/distribution plate having a series of alternating passages for respectively delivering gas flow to the cotton and for allowing gas flow to exit from the cotton, whereby relatively short path lengths are achieved; and

an air conditioner connected for driving a conditioned gas flow through said passages for delivering gas flow.

27. The machine of claim 26, which further comprises an aerosolizer for introducing aerosolized water into the conditioned gas flow for delivery to the cotton.

28. The machine of claim 27, wherein the volume mean diameter and geometric standard deviation of the aerosol size distribution are about 15 micrometers and 2.0, respectively.

29. A machine for conditioning cotton fiber being pneumatically transported by a gas flow, said machine comprising:

a high speed condenser in the form of a rotating perforated cylinder with inward gas flow such that fibers being transported are collected on said condenser as a thin mat, and subsequently re-delivered to the transport gas flow; and

an aerosolizer for introducing aerosolized water for delivery to the thin mat.

30. The machine of claim 29, wherein said thin mat is less than about 1 mm in thickness.

31. An gas flow permeability testing instrument, comprising:

a testing chamber;

a device for introducing individualized fibers into a gas flow stream for delivery to said testing chamber;

sensors in said gas flow stream enabling the determination of fiber mass delivered to said testing chamber;

a computer connected to said sensors for determining when a predetermined mass set point is reached, and outputting a control signal to terminate delivery of fibers to said testing chamber; and

a system for testing the permeability of a fiber sample within said testing chamber, and thereafter ejecting the fiber sample.

32. The instrument of claim 31, which further comprises a gravimetric balance for more precisely determining the mass of the fiber sample.

33. The instrument of claim 31, wherein:

said sensors in said gas flow stream comprise a volumetric flow rate sensor and an electro-optical mass concentration sensor; and wherein

said computer determines when the predetermined mass set point is reached by integrating over time the product of mass concentration and mass flow rate.

34. The instrument of claim 31, wherein:

said testing chamber has a movable wall to very the volume thereof; and which further comprises:

a gas flow system for driving a gas flow through said chamber with at least the gas flow rate and pressure difference measured so as to determine permeability;

an actuator driving said movable wall in a substantially continuous manner so as to compress the fiber sample and a transducer for measuring position of said movable wall of said chamber; and

a data processing device for acquiring at least gas flow rate, pressure difference, and position data at a sampling rate while said wall is moving.

35. A multiple-compression fiber gas flow permeability testing device, comprising:

a chamber adapted to receive a fiber sample of known mass, the chamber having a movable wall to vary the volume thereof;

a gas flow system for driving a gas flow through said chamber with at least the gas flow rate and pressure difference measured so as to determine permeability;

an actuator driving said movable wall in a substantially continuous manner so as to compress the fiber sample and a transducer for measuring position of said movable wall of said chamber; and

a data processing device for acquiring at least gas flow rate, and pressure difference, and position data at a sampling rate while said wall is moving.

36. The permeability testing device of claim 35, wherein said data processing device computes "micronaire" of the fiber sample.

37. The permeability testing device of claim 35, wherein said data processing device computes "maturity" of the fiber sample.

38. The permeability testing device of claim 35, wherein said data processing device computes "fineness" of the fiber sample.

39. The permeability testing device of claim 35, wherein said chamber receives a sample of cotton fiber.

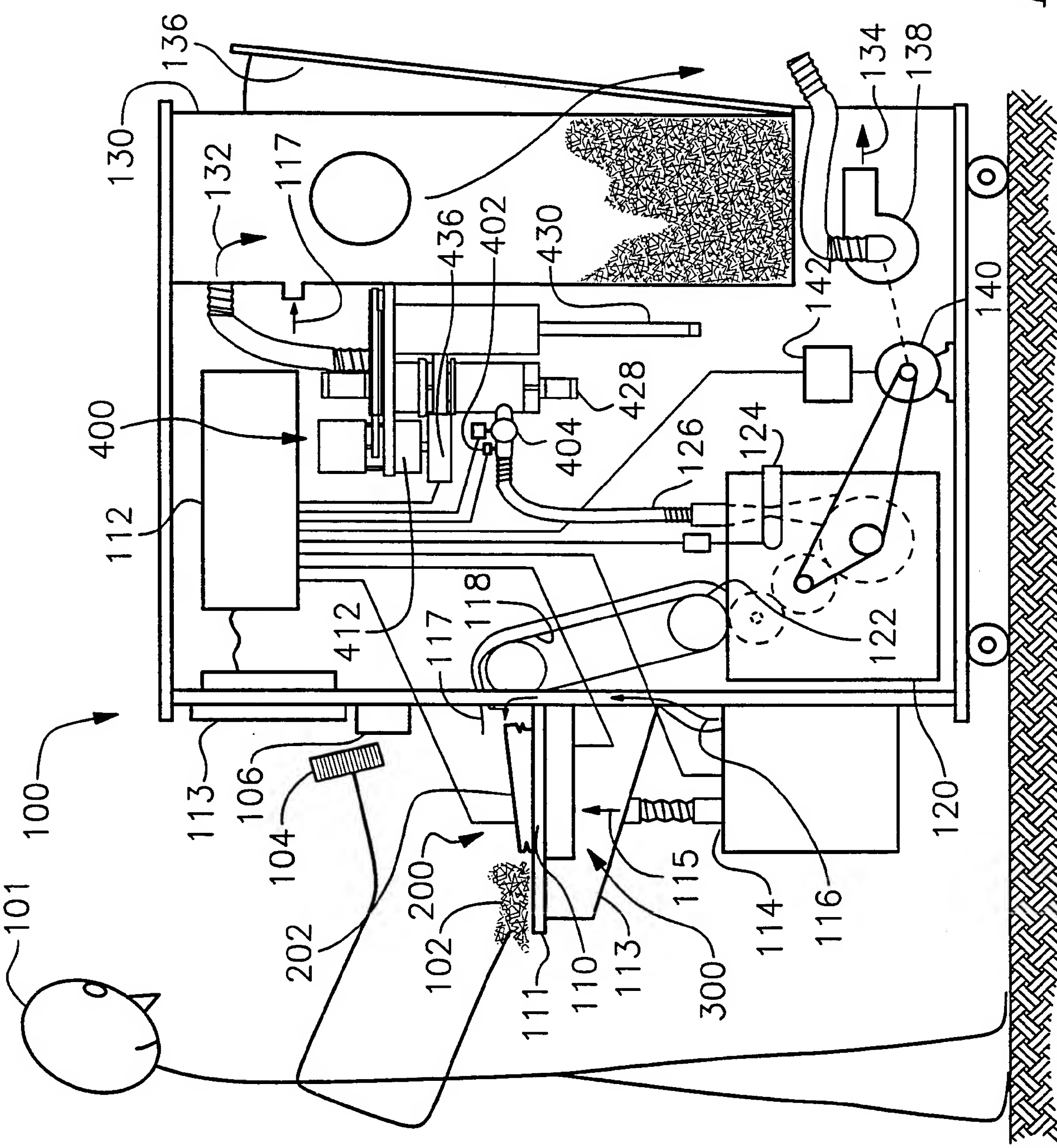
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Fig. 1

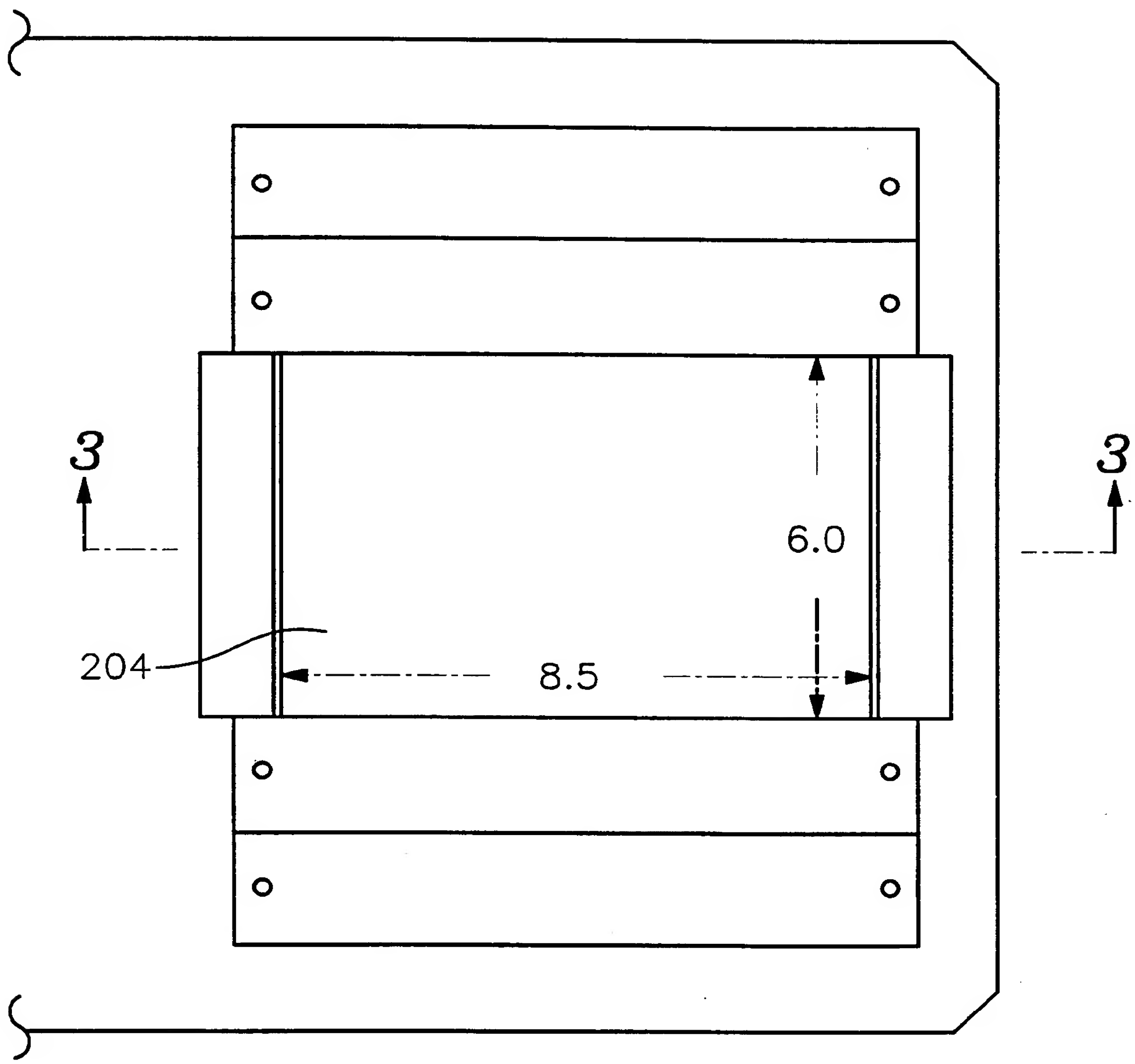


Fig. 2

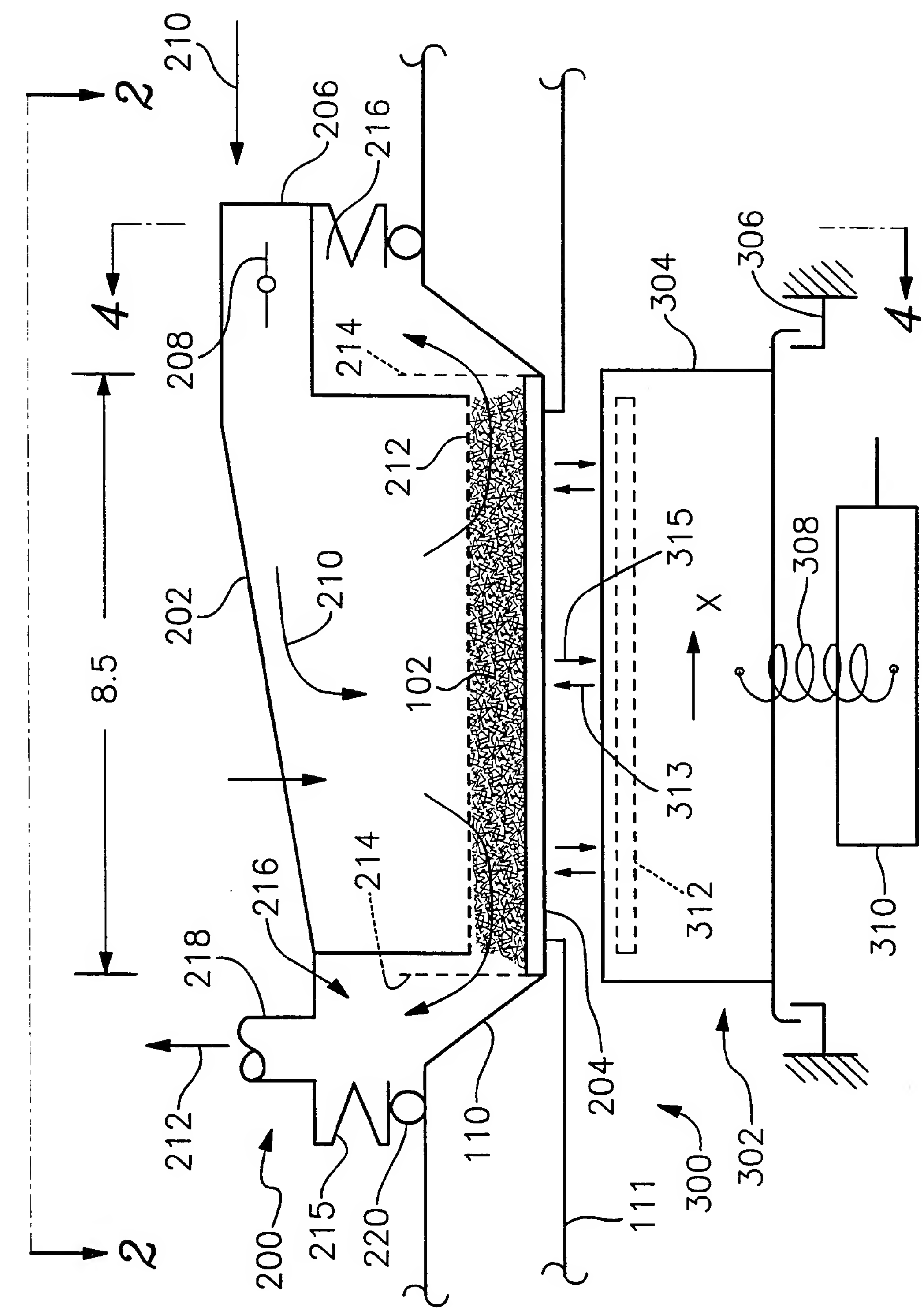
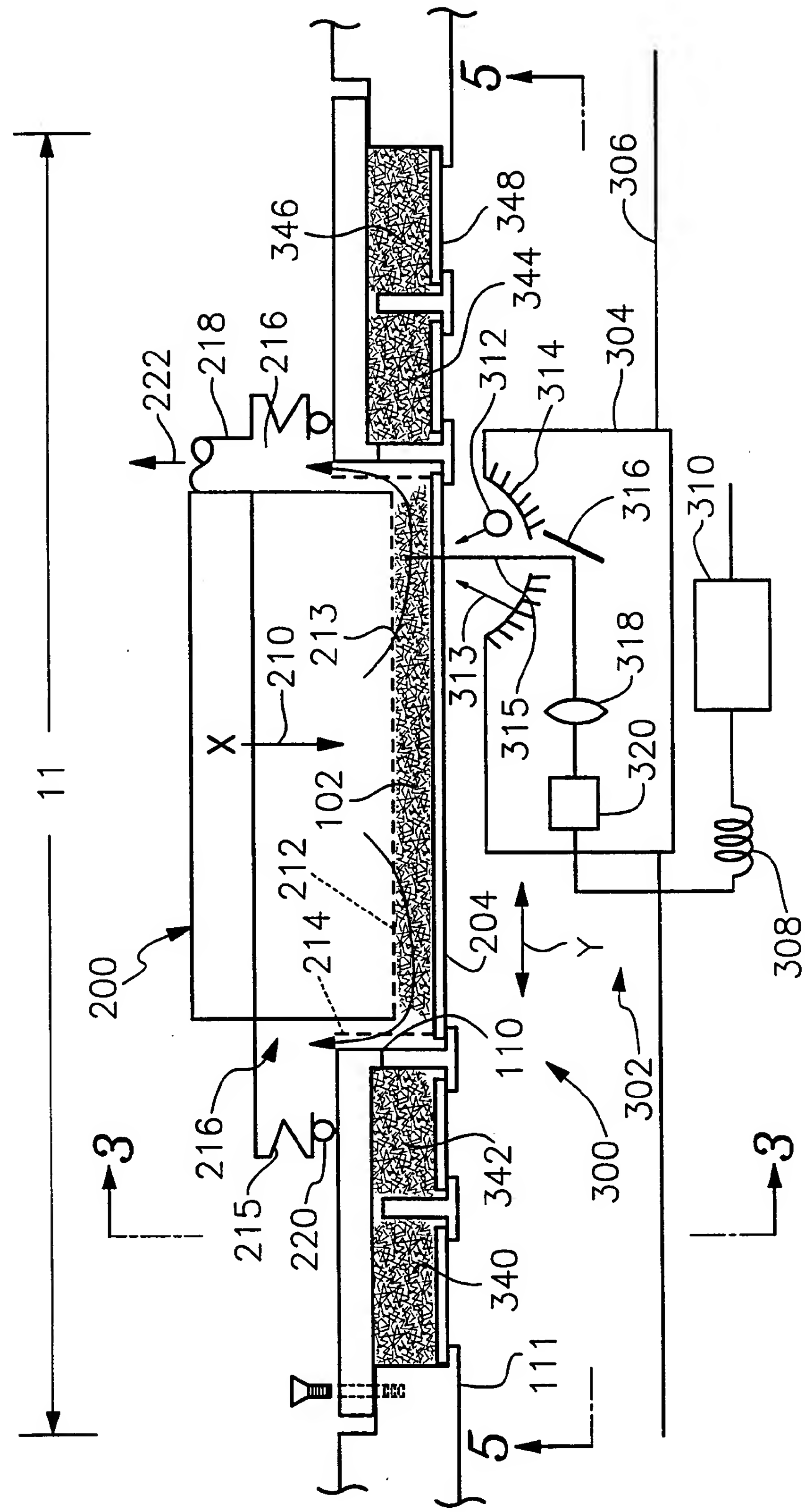


Fig. 3

SUBSTITUTE SHEET (RULE 26)



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X
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Fig. 4

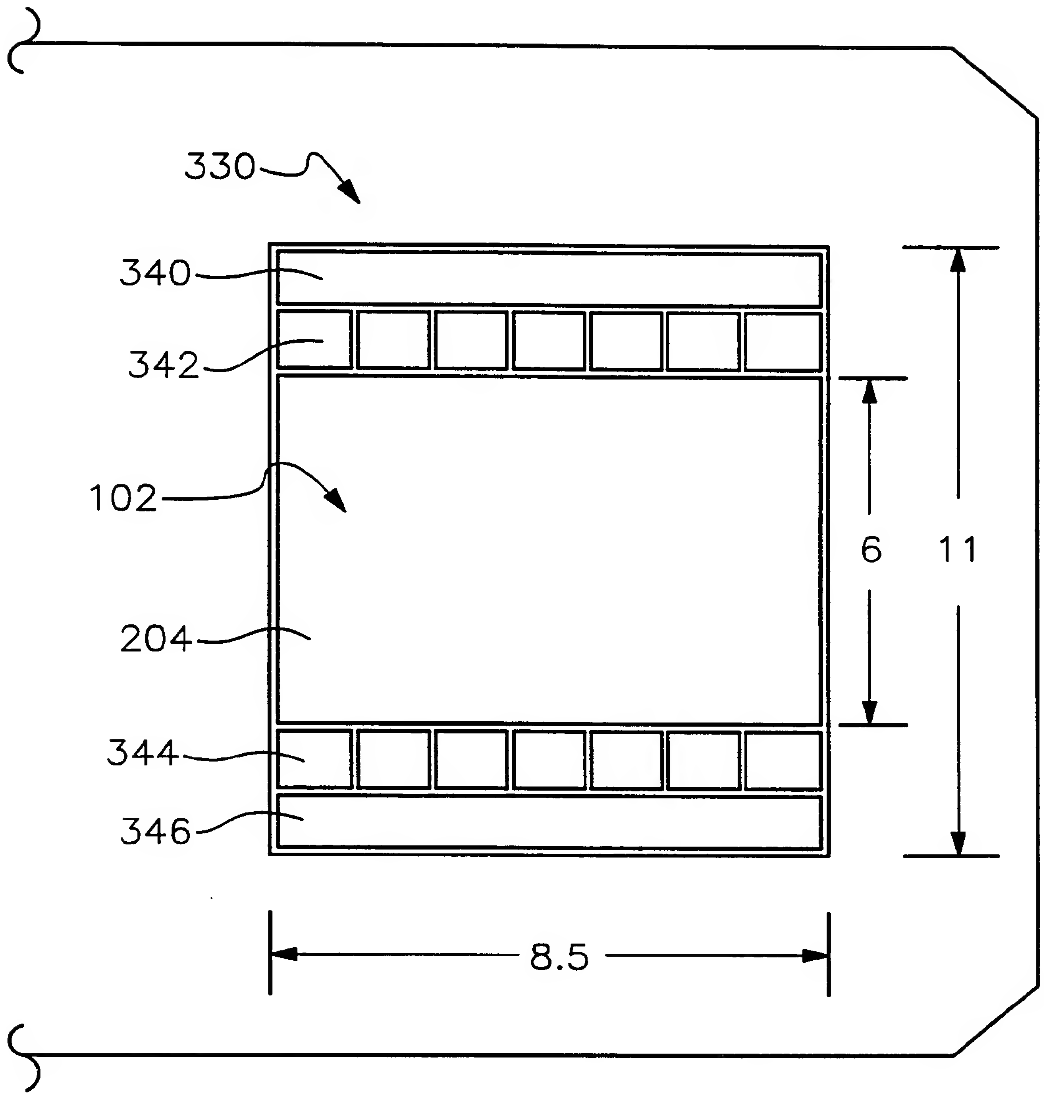


Fig. 5

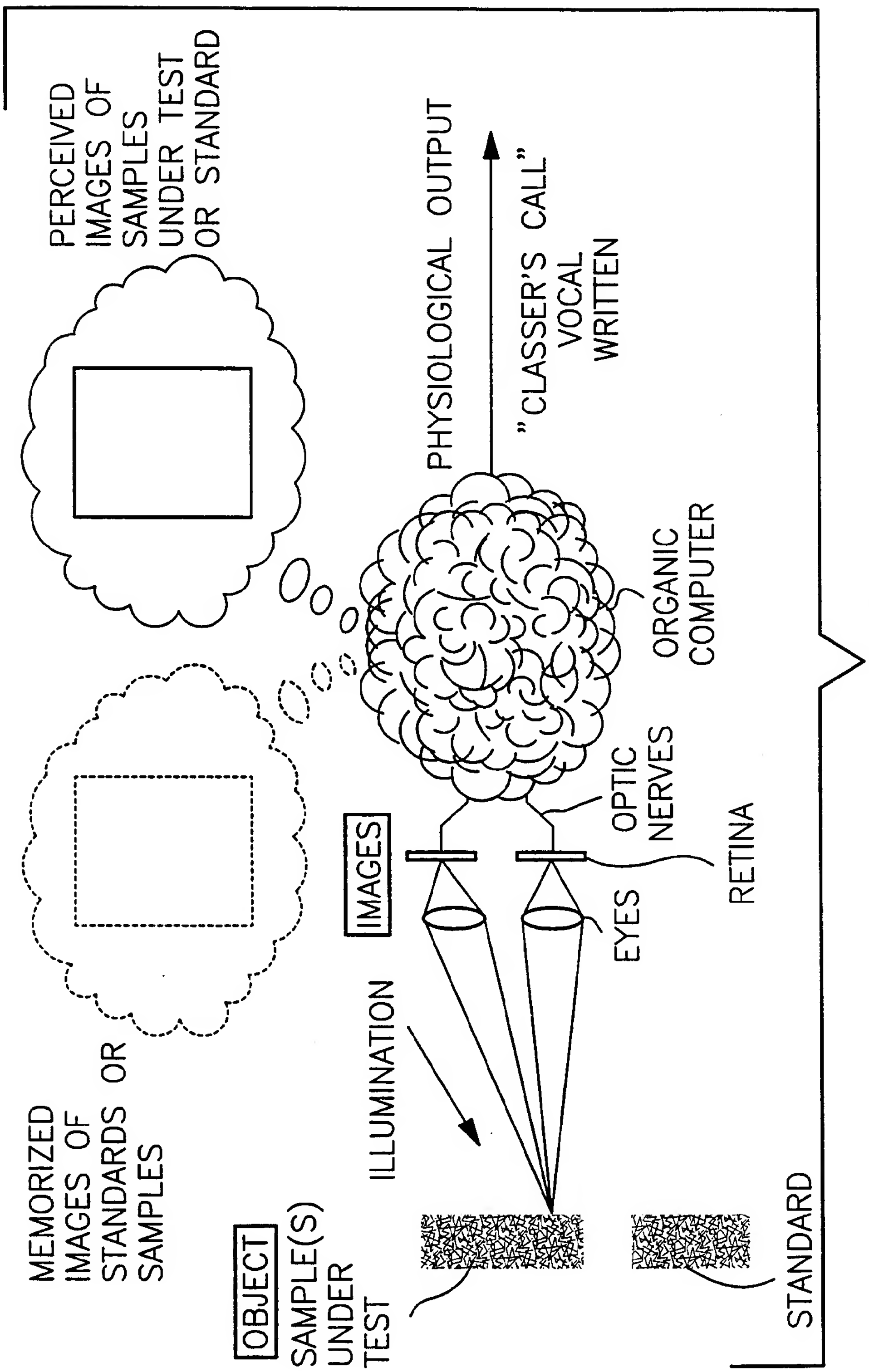

MEMORIZED IMAGES OF STANDARDS OR SAMPLES
PERCEIVED IMAGES OF SAMPLES UNDER TEST OR STANDARD
OBJECT
SAMPLE(S) UNDER TEST
ILLUMINATION
IMAGES
PHYSIOLOGICAL OUTPUT
"CLASSER'S CALL"
VOCAL
WRITTEN
EYES
RETINA
OPTIC NERVES
ORGANIC COMPUTER
STANDARD
STANDARD

Fig. 6

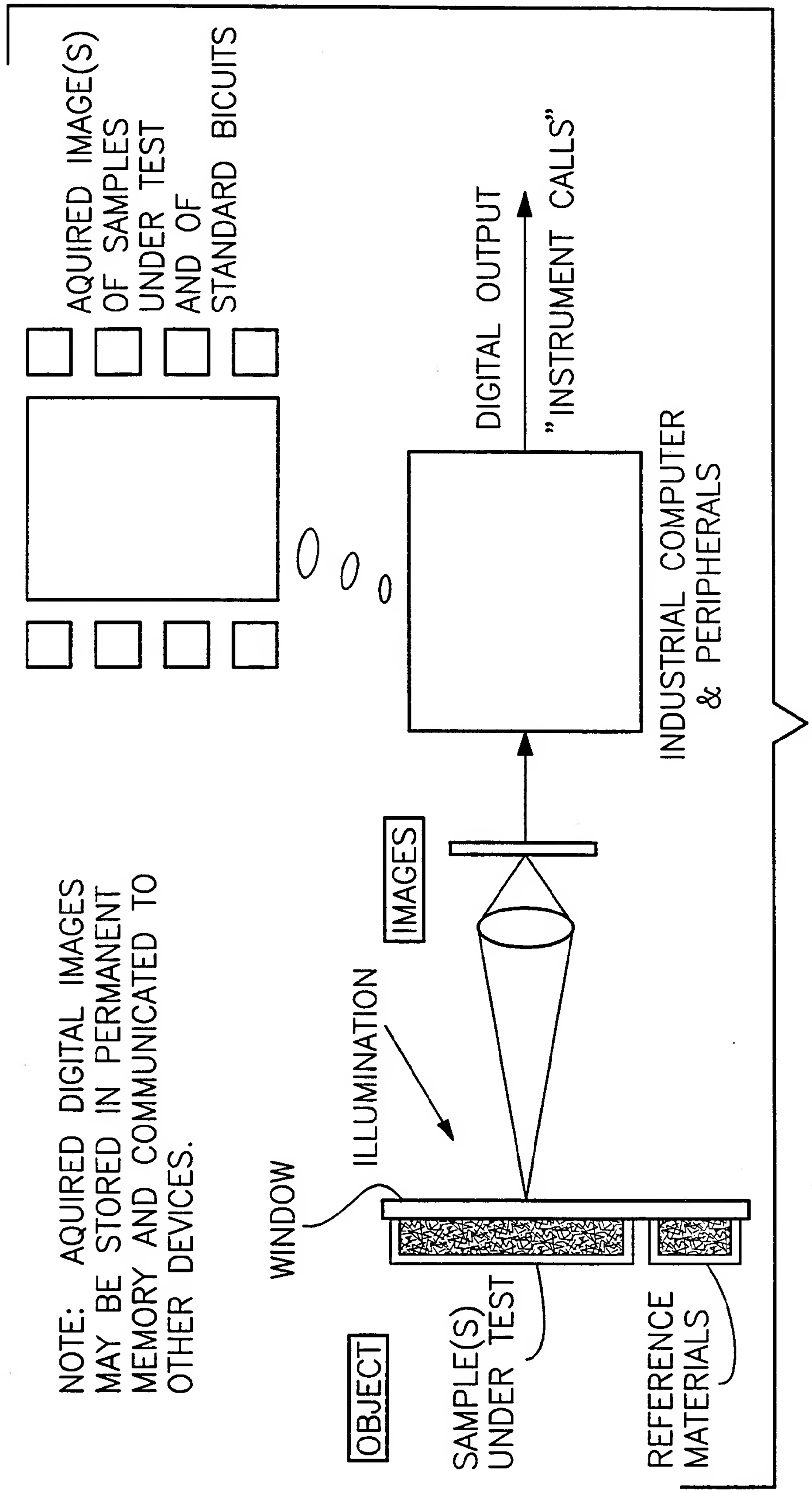
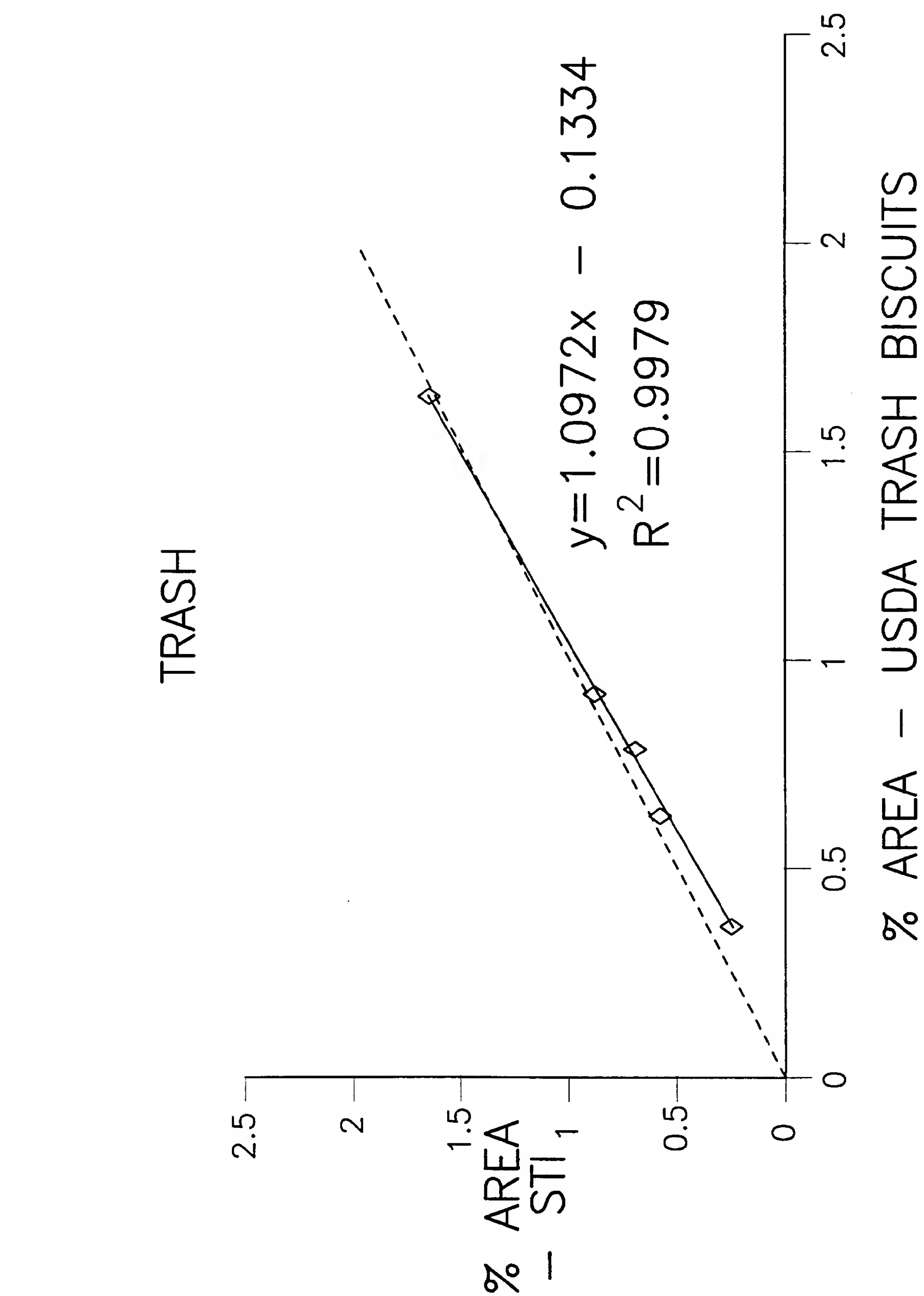

NOTE: AQUIRED DIGITAL IMAGES MAY BE STORED IN PERMANENT MEMORY AND COMMUNICATED TO OTHER DEVICES.
OBJECT
WINDOW
ILLUMINATION
IMAGES
SAMPLE(S) UNDER TEST
REFERENCE MATERIALS
AQUIRED IMAGE(S) OF SAMPLES UNDER TEST AND OF STANDARD BICUITS
DIGITAL OUTPUT
"INSTRUMENT CALLS"
INDUSTRIAL COMPUTER & PERIPHERALS

Fig. 7


TRASH
y=1.0972x − 0.1334
R^2=0.9979
% AREA − STI
% AREA − USDA TRASH BISCUITS
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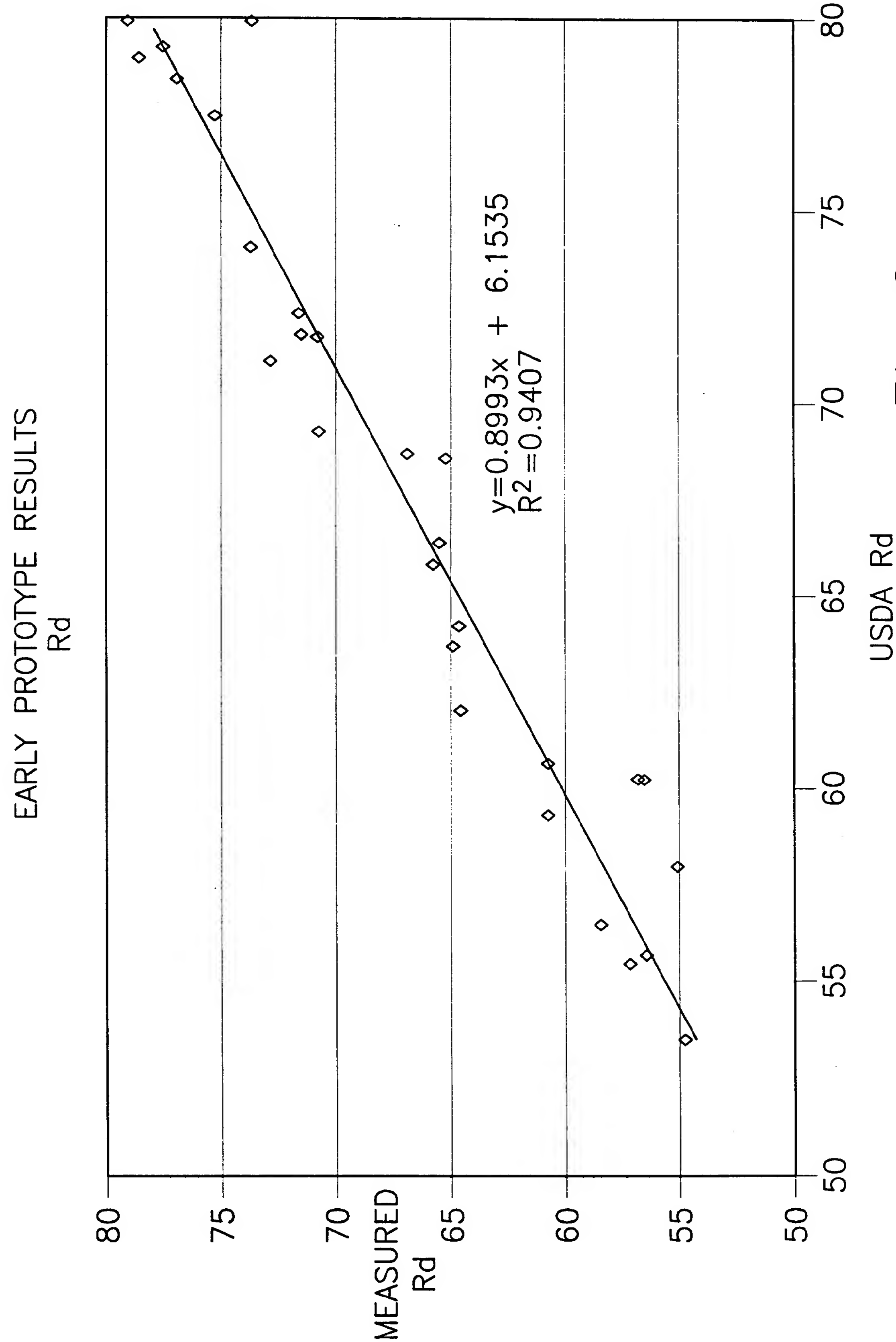
0.5
1
1.5
2
2.5

Fig. 8


EARLY PROTOTYPE RESULTS
Rd
y=0.8993x + 6.1535
R2=0.9407
USDA Rd
MEASURED
Rd
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55
60
65
70
75
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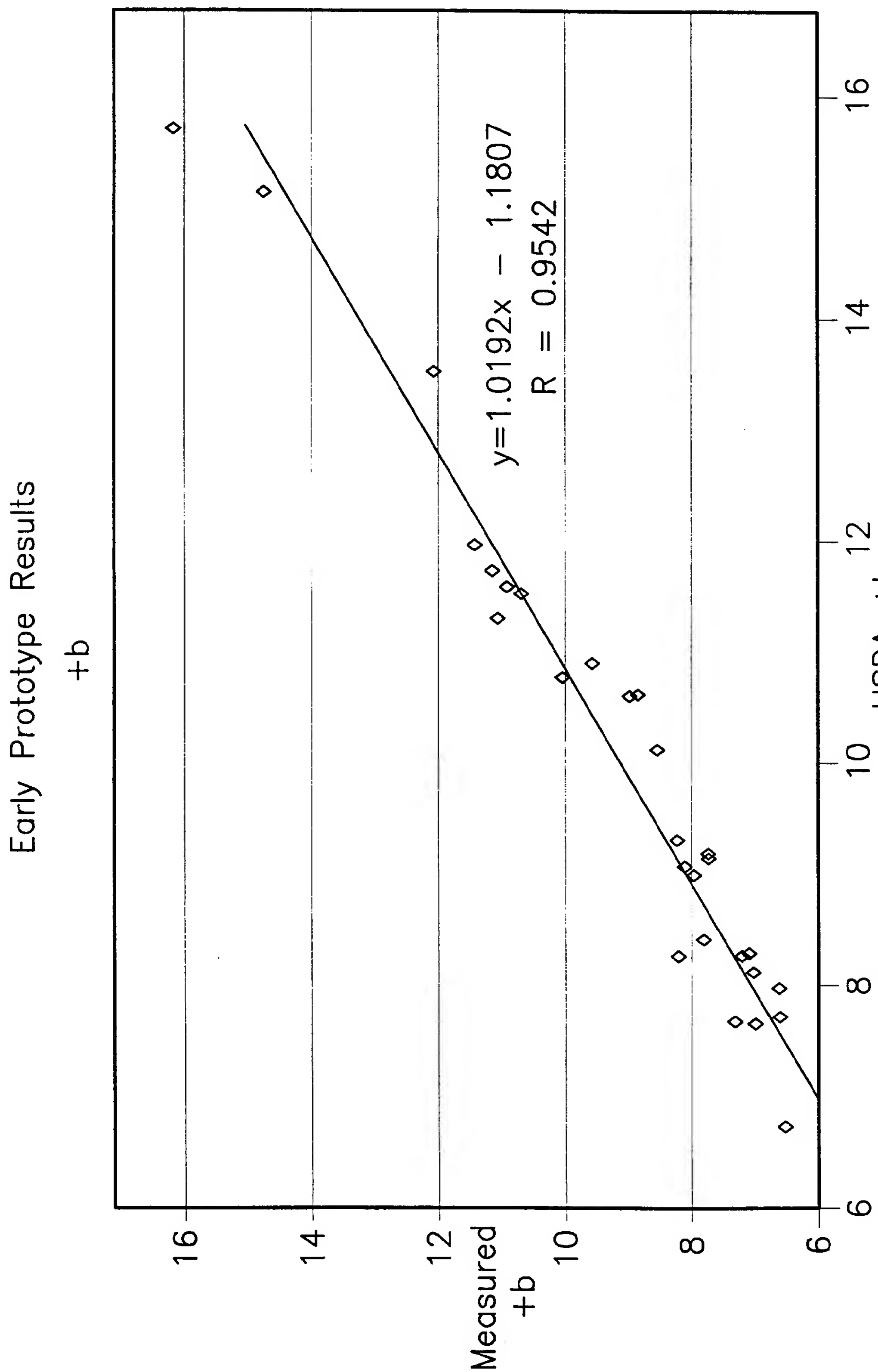
Fig. 9


Early Prototype Results
+b
y=1.0192x − 1.1807
R = 0.9542
Measured +b
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14
12
10
8
6
USDA +b
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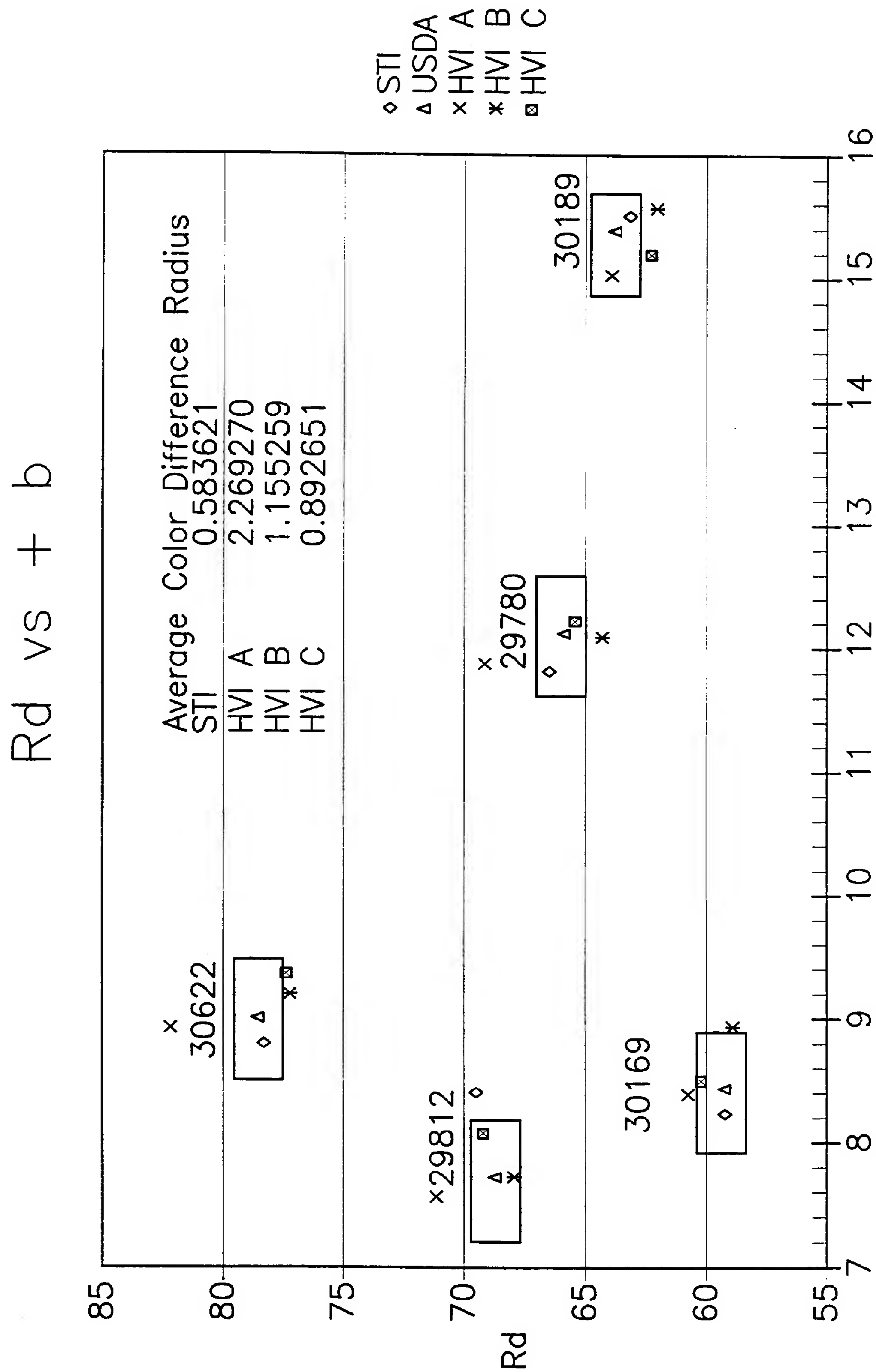
Fig. 10


Rd vs + b
Average Color Difference Radius
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HVI A 2.269270
HVI B 1.155259
HVI C 0.892651
STI
USDA
HVI A
HVI B
HVI C
30622
29812
30169
29780
30189
Rd
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Fig. 11

FIG. 12

SUBSTITUTE SHEET (RULE 26)

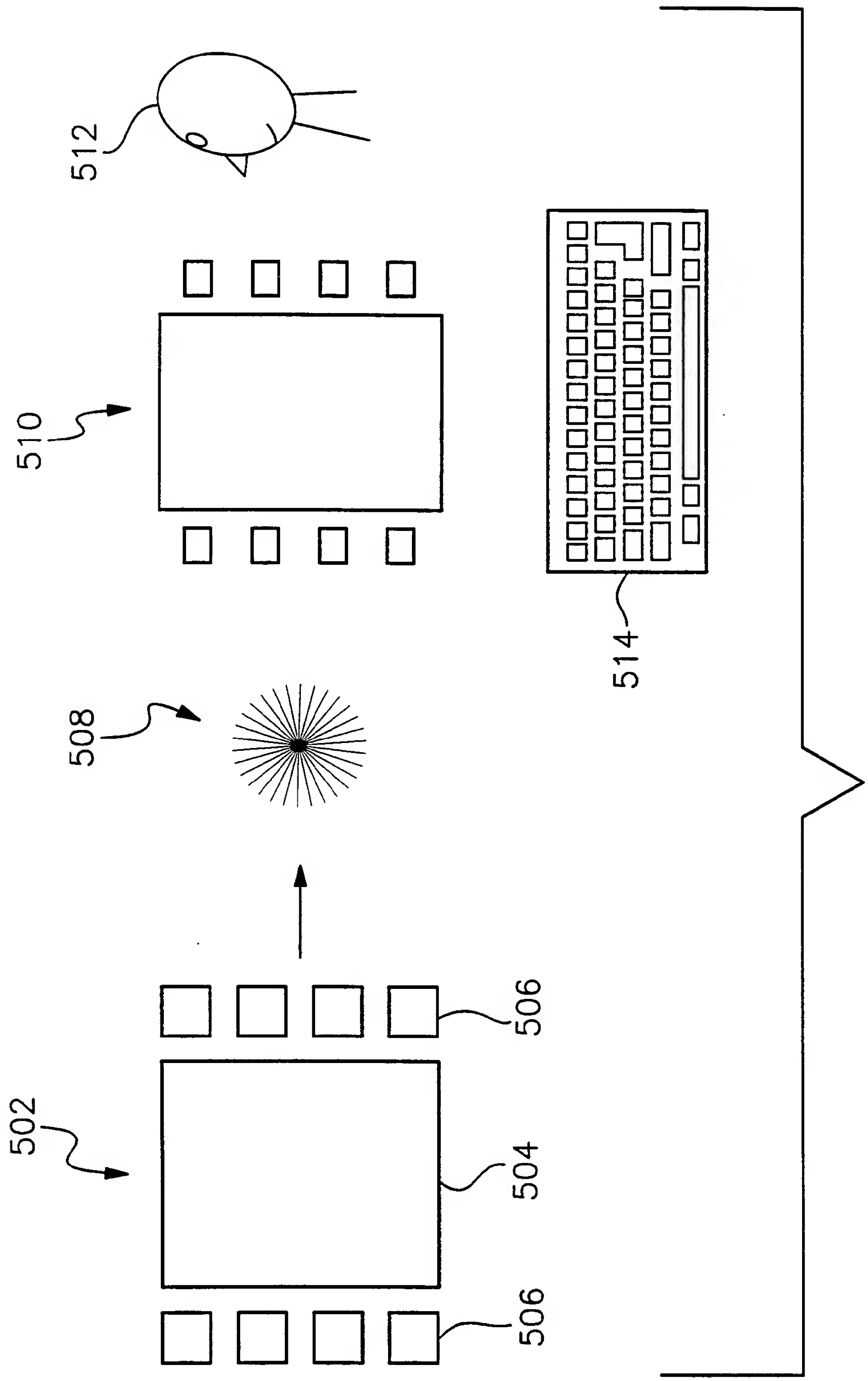

Fig. 13

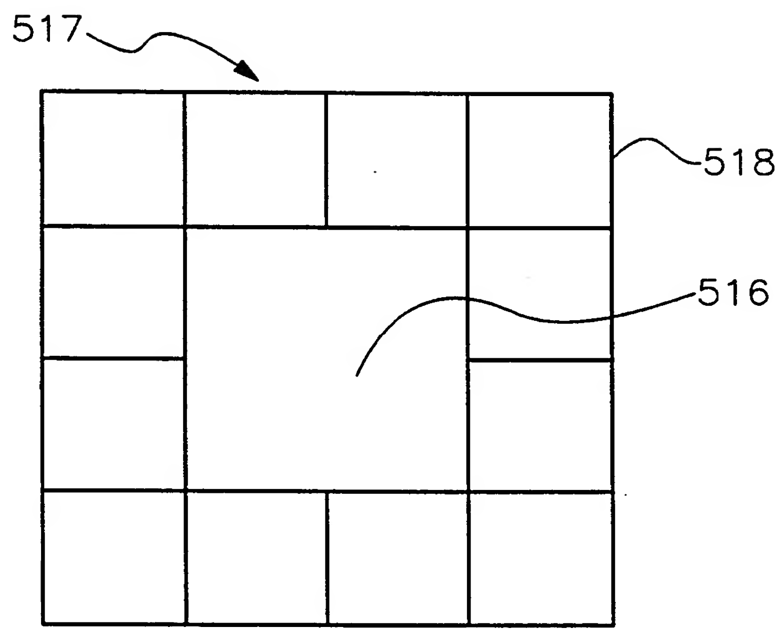

Fig. 14

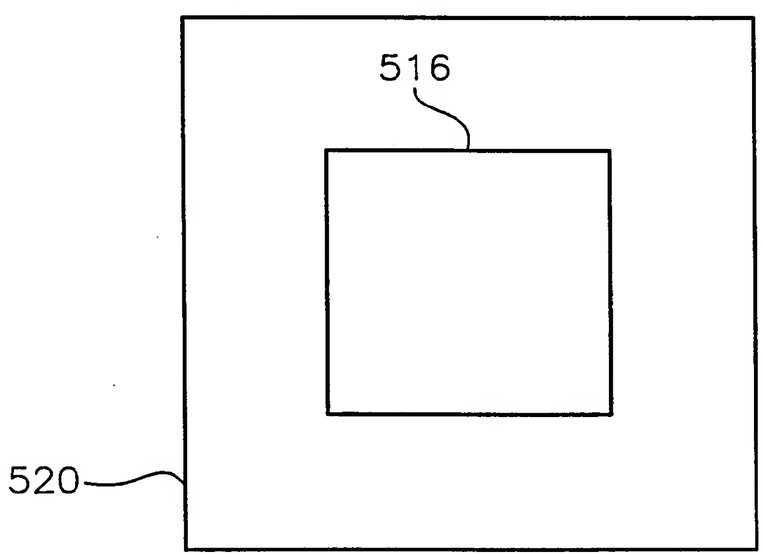

Fig. 15

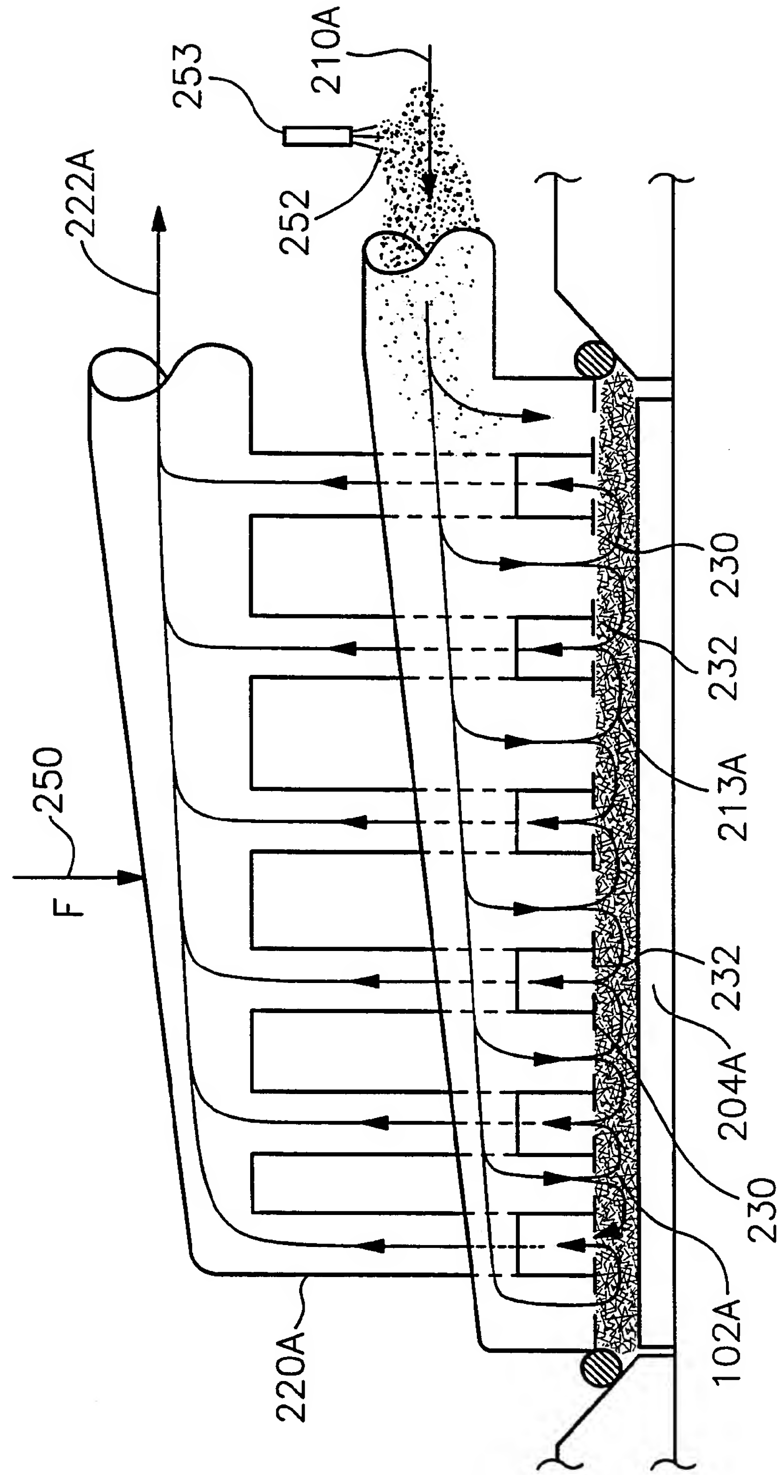

Fig. 16

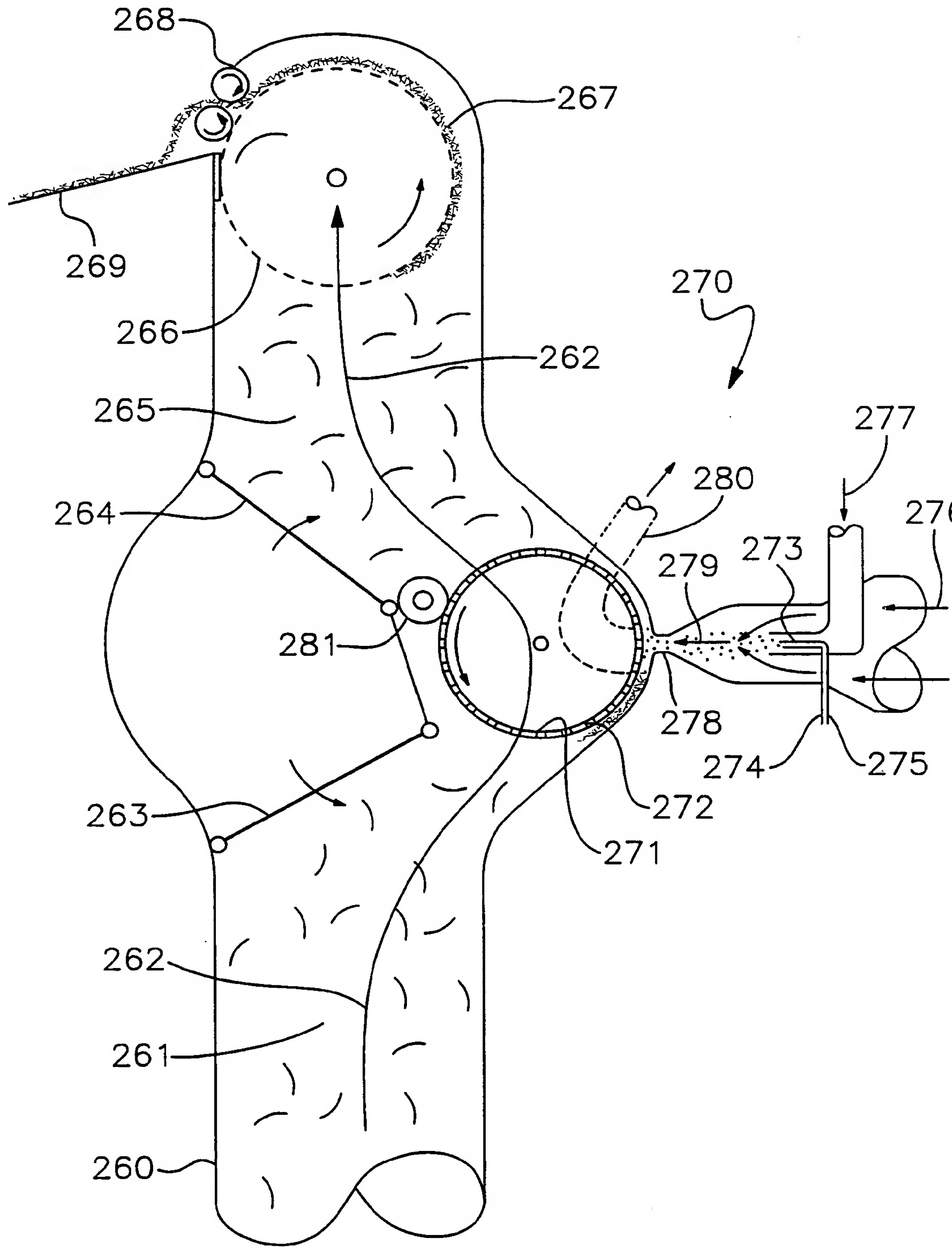
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Fig. 17

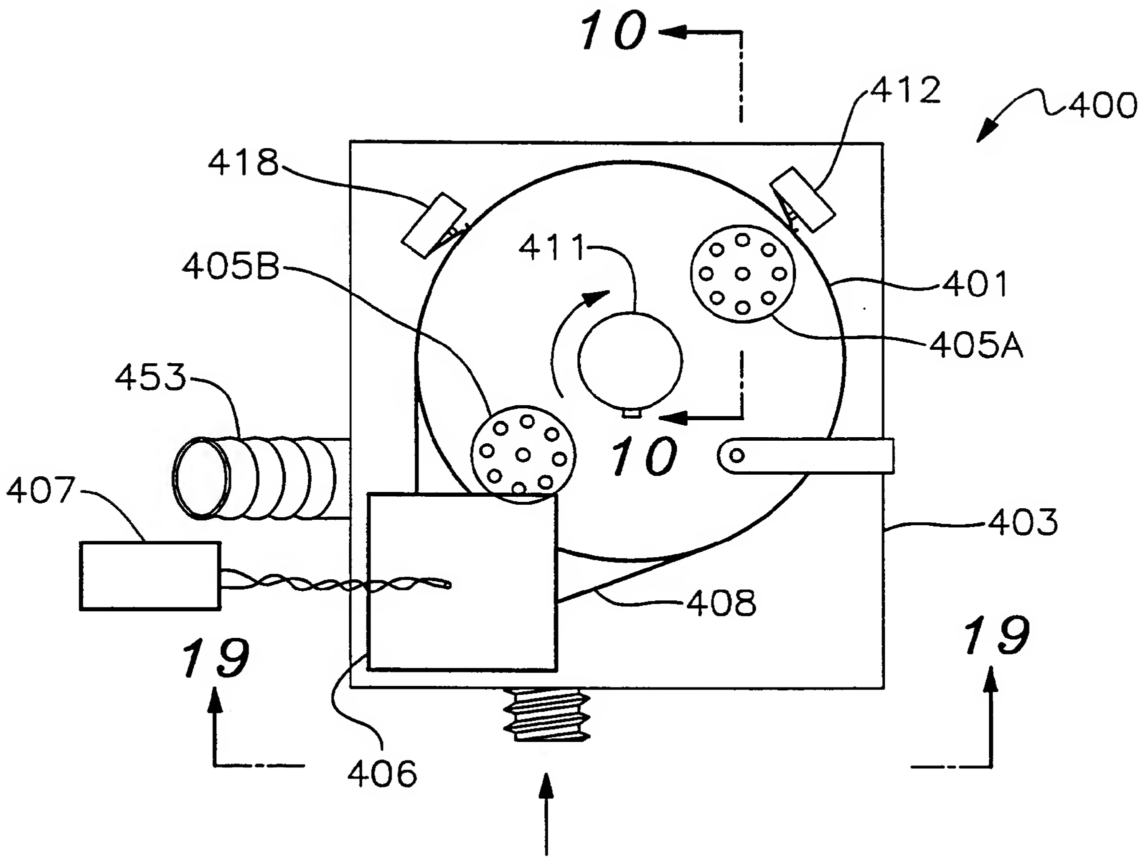
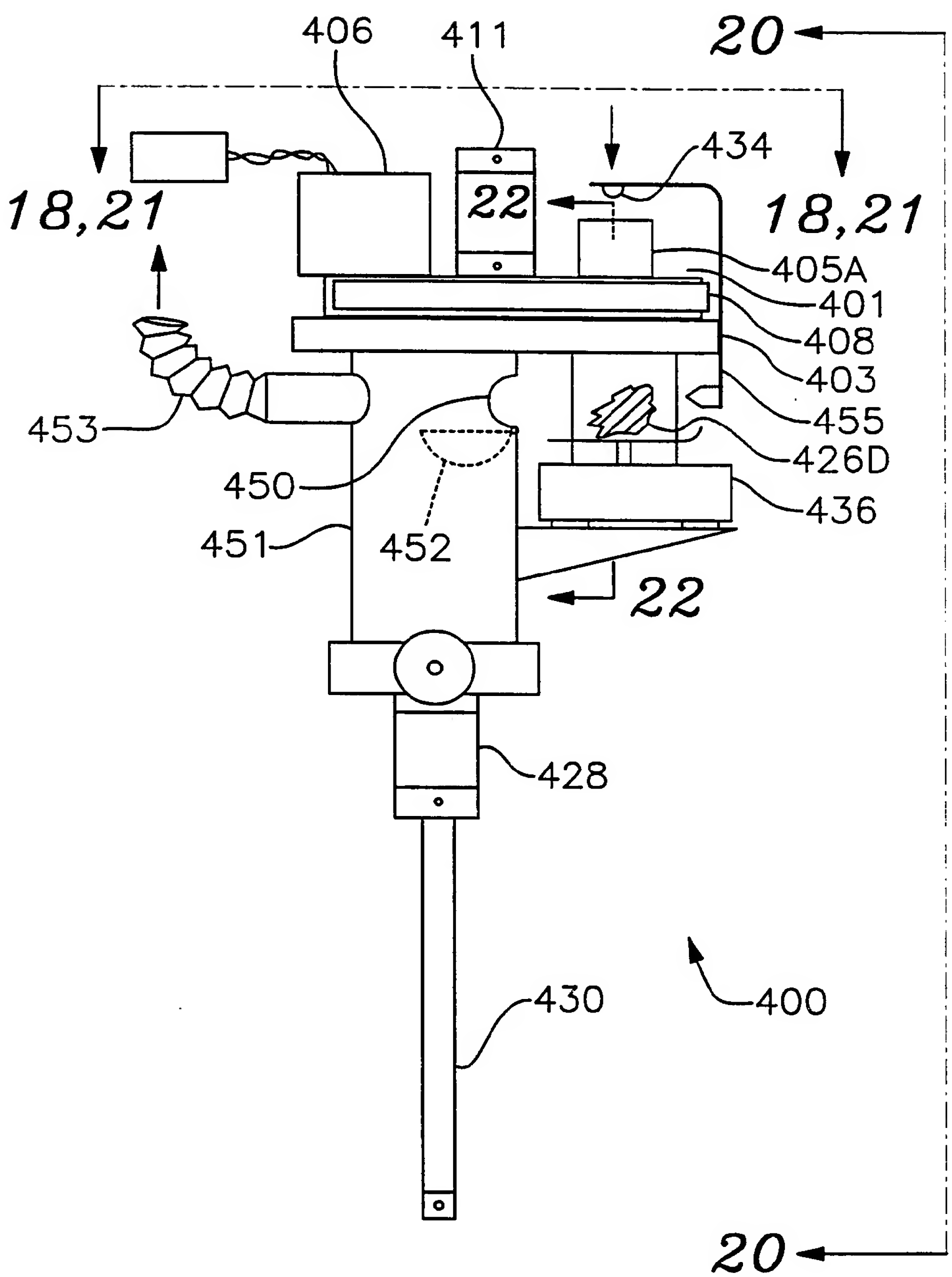


Fig. 18


406
411
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434
18,21
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18,21
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426D
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22
428
430
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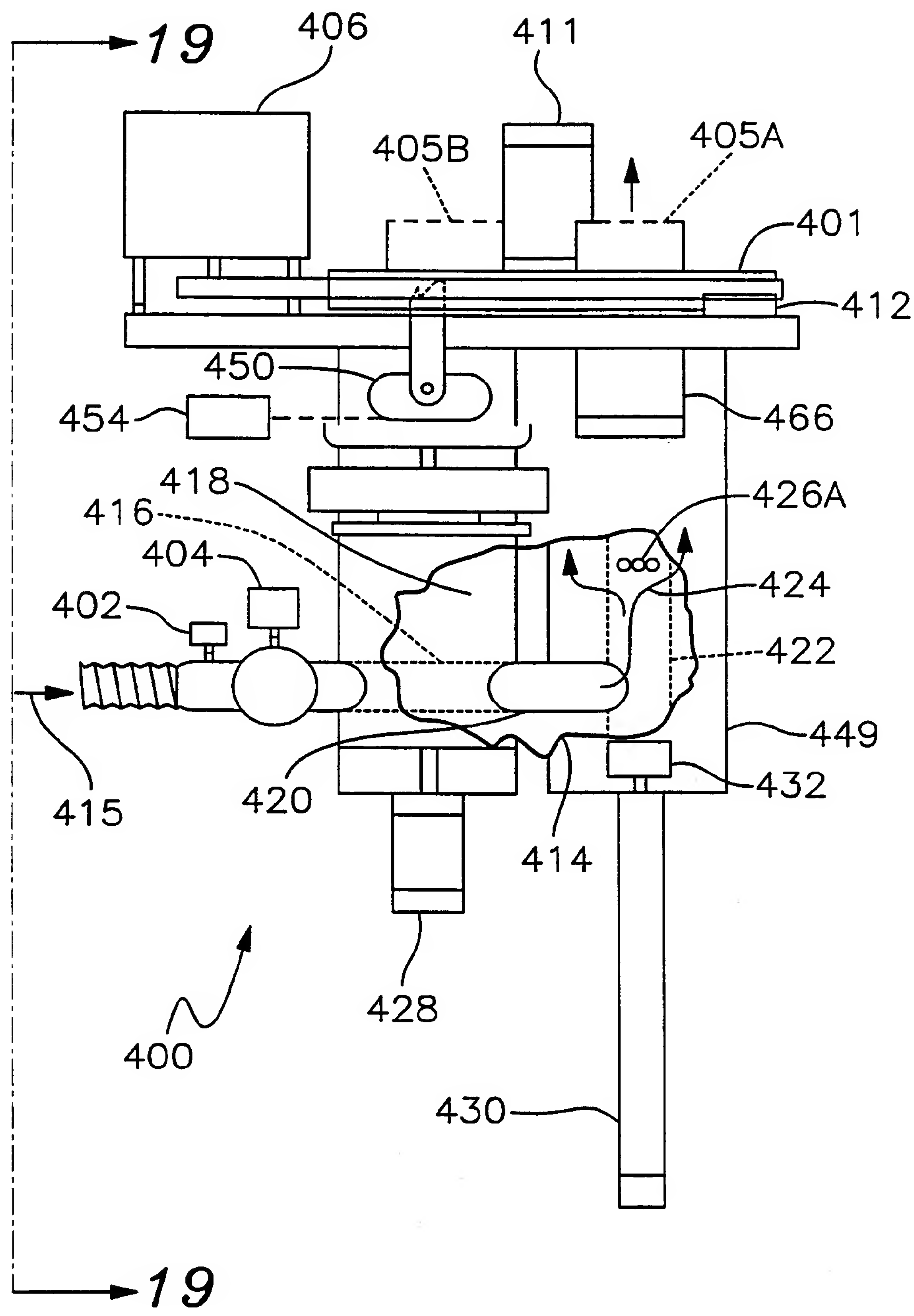
20

Fig. 19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405A
401
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19

Fig. 20

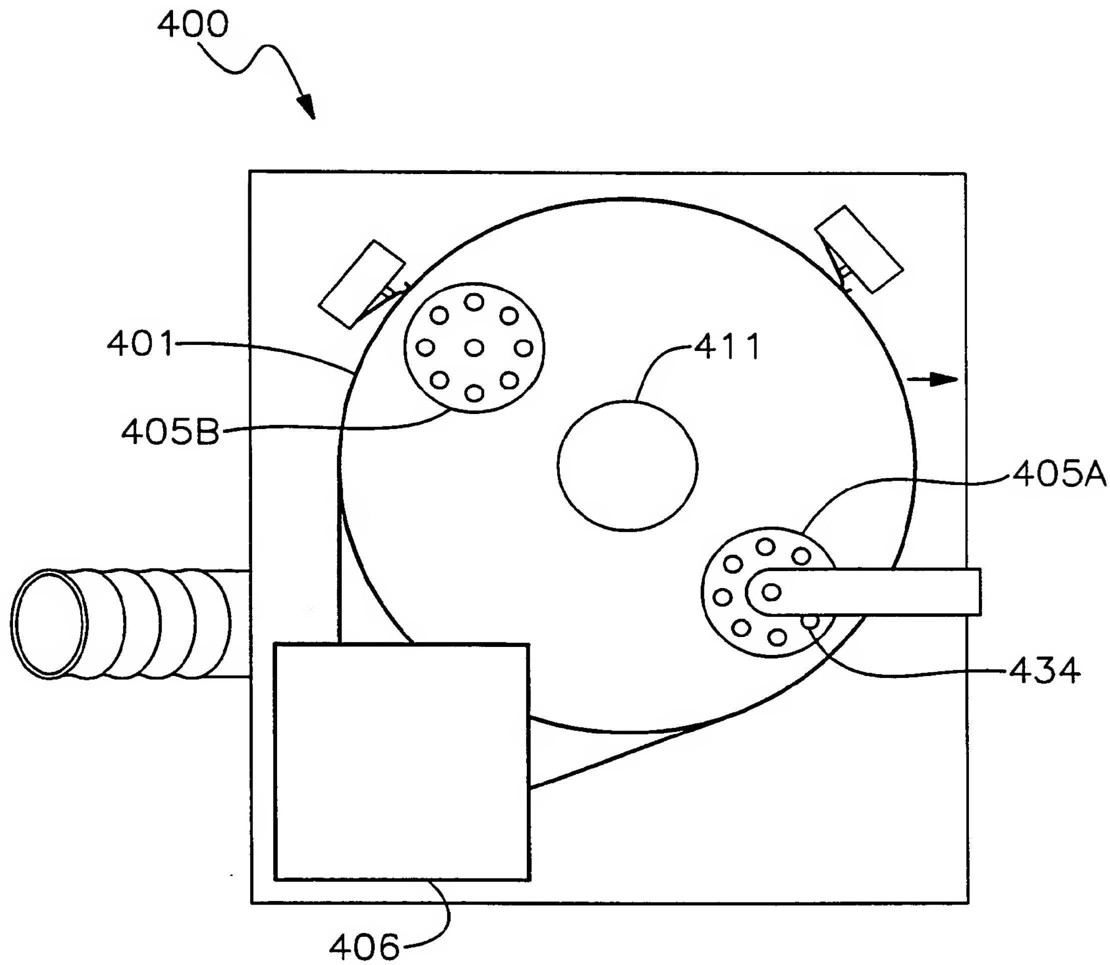

Fig. 21

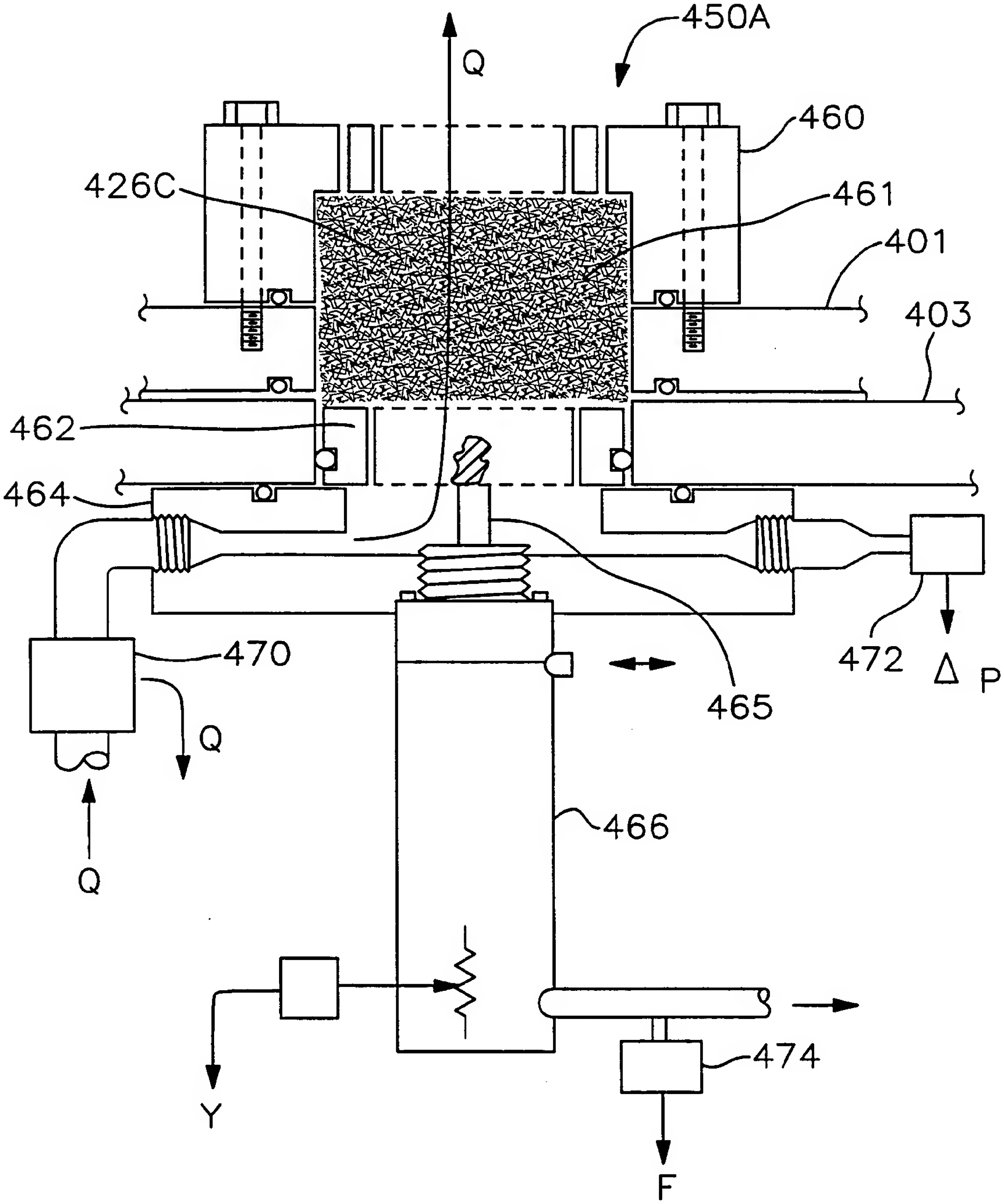

Fig. 22

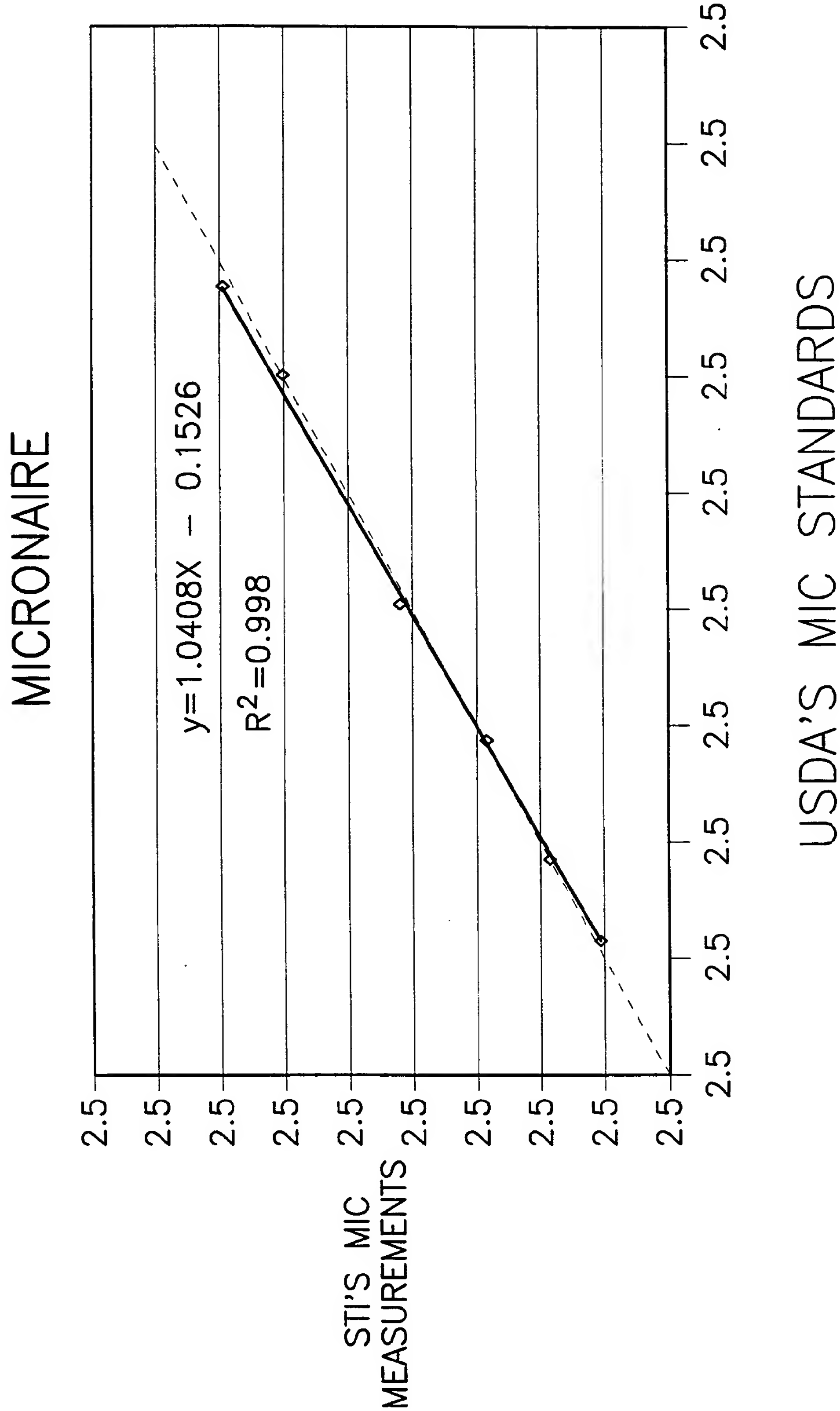
MICRONAIRE
y=1.0408X – 0.1526
R2=0.998
2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
STI'S MIC MEASUREMENTS
2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
USDA'S MIC STANDARDS

Fig. 23